THE MINERAL INDUSTRY

THE MINERAL INDUSTRY

ITS

STATISTICS, TECHNOLOGY AND TRADE

DURING

1916

FOUNDED BY RICHARD P. ROTHWELL

EDITED BY

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THE STATE GEOLOGICAL SURVEYS

Of the 48 States of the Union, nearly all in which the mining industry is important have organized geological surveys. Certain States which have no geological survey have officials who give attention to the mining industry. Thus, California has a State mineralogist, while Idaho has a State mine inspector who collects statistics of mineral production. The States having organized geological surveys, together with the names and addresses of the respective State geologists, as of Jan. 1, 1917, are given in the following list:

STATE GEOLOGISTS.

State.	Name and Address.	State.	Name and Address.
Alabama......	Eugene A. Smith, University.	Nebraska.....	E. H. Barbour, Lincoln.
Arizona.......	Charles Clapp, Tucson.	New Jersey...	H. B. Kümmel, Trenton.
Arkansas......	N. F. Drake, Fayetteville.	New Mexico..	Chas. T. Kirk, Albuquerque.
Connecticut...	Prof. Herbert E. Gregory, Supt., New Haven.	New York....	John M. Clarke, Albany.
		N. Carolina...	Joseph Hyde Pratt, Chapel Hill.
Colorado......	R. D. George, Director, Boulder.	N. Dakota....	A. G. Leonard, Grand Forks.
Florida.......	E. H. Sellards, Tallahassee.	Ohio.........	J. A. Bownocker, Columbus.
Georgia.......	S. W. McCallie, Atlanta.	Oklahoma....	C. W. Shannon, Norman.
Illinois........	F. W. DeWolf, Director, Urbana	Oregon.......	H. M. Parks, Director, Corvallis
Indiana.......	Edward Barrett, Indianapolis.	Pennsylvania .	Richard R. Hice, Beaver.
Iowa.........	Geo. F. Kay, Iowa City.	Rhode Island..	Chas. W. Brown, Providence.
Kansas.......	Dr. Raymond C. Moore, Lawrence.	S. Carolina....	Stephen Taber, Columbia.
		S. Dakota.....	Freeman Ward, Vermilion.
Kentucky.....	J. B. Hoeing, Frankfort.	Tennessee.....	A. H. Purdue, Nashville.
Louisiana.....	F. V. Emerson, Director, Baton Rouge.	Texas........	J. A. Udden, Austin.
		Vermont......	G. H. Perkins, Burlington.
Maryland.....	William Bullock Clark, Baltimore.	Virginia......	Thos. L. Watson, Charlottesville.
Michigan......	R. C. Allen, Lansing.	Washington...	Henry Landes, Seattle.
Minnesota....	W. H. Emmons, Minneapolis.	West Virginia.	I. C. White, Morgantown.
Mississippi....	E. N. Lowe, Jackson.	Wisconsin.....	W. O. Hotchkiss, Madison.
Missouri......	H. A. Buchler, Rolla.	Wyoming.....	L. W. Trumbull, Cheyenne.
Montana.....	J. P. Rowe, Missoula.		

STATE MINE INSPECTORS, COMMISSIONERS, ETC.

State.	Name and Address.
Alabama...............	C. H. Nesbit, Chief Mine Inspector, Birmingham.
Alaska.................	Summer S. Smith, Mine Inspector, Juneau.
Arizona................	G. H. Bolin, State Mine Inspector, Phoenix. Charles F. Willis, Director, State Bureau of Mines.
Arkansas.............	John H. Page, Commissioner, Bureau of Mines, Manufactures and Agriculture, Little Rock; John T. Fuller, State Mineralogist; T. H. Shaw, State Mine Inspector, Midland.
California.............	F. McN. Hamilton, State Mineralogist, San Francisco.
Colorado..............	Fred Carroll, Commissioner, James Dalrymple, State Inspector of Coal Mines, Denver.
Idaho..................	R. N. Bell, State Mine Inspector, Boise.
Indiana................	Michael Scollard, Deputy Inspector of Mines, Indianapolis.
Iowa....................	E. M. Gray, Pres. State Mining Board, Des Moines.
Kansas.................	John Pellegrino, Chief Mine Inspector, Pittsburgh.
Kentucky..............	C. J. Norwood, Chief Inspector of Mines, Lexington.
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Pennsylvania..........	James Roderick, Chief Department of Mines, Harrisburg.
South Dakota..........	O. E. Ellerman, State Mine Inspector, Lead.
Tennessee.............	R. A. Shiflett, Chief Mine Inspector, Nashville.
Texas.................	B. S. Gentry, State Mine Inspector, Rockdale.
Utah..................	J. E. Pettit, State Mine Inspector, Salt Lake City.
Virginia...............	A. G. Lucas, Mine Inspector, Richmond.
Washington............	Jas. Bagley, State Inspector of Coal Mines, Seattle.
West Virginia..........	Earl Henry, Chief, Department of Mines, Charleston.

VALUE OF FOREIGN COINS

ESTIMATE BY DIRECTOR OF THE MINT, JAN. 1, 1917.

Country.	Standard.	Monetary Unit.	Value in Terms of U.S. Gold Dollar.	Coins.
Argentine Republic.	Gold...	Peso................	$0.9648	Gold: argentine ($4.824) and ½ argentine. Silver: peso and divisions. Currency: Depreciated paper, convertible at 44 per cent. of face value.
Austria-Hungary..	Gold...	Crown..............	.2026	Gold: 10 and 20 crowns. Silver, 1 and 5 crowns. Member of Latin Union; gold is the actual standard.
Belgium..........	Gold...	Franc...............	.1930	Gold: 10 and 20 francs. Silver: 5 francs.
Bolivia...........	Gold...	Boliviano...........	.3893	Silver: boliviano and divisions, 12½ bolivianos equal 1 pound sterling.
Brazil............	Gold...	Milreis..............	.5462	Gold: 5, 10 and 20 milreis. Silver: ½, 1 and 2 milreis. Currency: Government paper. Exchange rate about 25 cts. to the milreis.
British Colonies in America.	Gold...	Dollar..............	1.0000	....
in Australasia and Africa.	Gold...	Pound sterling.......	4.8665	....
Central America. Costa Rica.	Gold...	Colon..............	.4653	Gold: 2, 5, 10 and 20 colons ($9.307) Silver: 5, 10, 25 and 50 centimos.
British Honduras.	Gold...	Dollar..............	1.0000	....
Nicaragua......	Gold ..	Cordoba............	1.0000	....
Guatemala... / Honduras.... / Salvador.....	Silver .	Peso................	.5439	Silver: peso and divisions. Guatemala: Currency, inconvertible paper, exchange rate 40 pesos = $1.00. Honduras: Currency, bank notes. Salvador: Currency, convertible into silver on demand.
Chile............	Gold...	Peso................	.3650	Gold: escudo ($1.825), doubloon ($3.650), and condor ($7.300). Silver: peso and divisions. Currency: Inconvertible paper; exchange rate, approximately, $0.14.
China..	Silver	Tael.. Amoy.......	.8917	The tael is a unit of weight; not a coin. The customs unit is the Haikwan tael. The values of other taels are based on their relation to the value of the Haikwan tael.
		Canton......	.8890	
		Cheefoo.....	.8529	
		Chin Kiang..	.8711	
		Fuchau......	.8248	
		Haikwan (customs)	.9073	
		Hankow.....	.8343	
		Kiaochow....	.8641	
		Nankin......	.8824	
		Niuchwang...	.8362	
		Ningpo......	.8573	
		Peking......	.8693	
		Shanghai....	.8145	
		Swatow......	.8237	
		Takau.......	.8974	
		Tientsin.....	.8641	
		Dollar Yuan	.5843	....
		Dollar Hongkong...	.5865	....
		British......	.5865	....
		Mexican.....	.5908	....
Colombia........	Gold...	Dollar..............	1.0000	Gold: condor ($9.647) and double condor. Silver: peso. Currency: Inconvertible paper; exchange rate, approximately, $105 paper to $1 gold.
Cuba............	Gold..	Peso...............	1.0000	
Denmark.........	Gold...	Crown..............	.2680	Gold: 10 and 20 crowns.
Ecuador.........	Gold...	Sucre..............	.4867	Gold: 10 sucres ($4.8665). Silver: sucre and divisions.

NOTE.—The coins of silver-standard countries are valued by their pure silver contents, at the average market price of silver for the three months preceding January 1, 1917.

Country.	Standard.	Monetary Unit.	Value in Terms of U.S. Gold Dollar.	Coins.
Egypt	Gold...	Pound (100 piasters)	4.9431	Gold: pound (100 piasters), 5, 10, 20 and 50 piasters. Silver: 1, 2, 5, 10 and 20 piasters. The actual standard is the British pound sterling, which is legal tender for 97½ piasters.
Finland	Gold...	Mark	.1930	Gold: 20 marks ($3.859), 10 marks ($1.93).
France	Gold...	Franc	.1930	Gold: 5, 10, 20, 50 and 100 francs. Silver 5 francs. Member of Latin Union; gold is the actual standard.
German Empire	Gold...	Mark	.2382	Gold: 5, 10 and 20 marks.
Great Britain	Gold...	Pound sterling	4.8665	Gold: sovereign (pound sterling) and ½ sovereign.
Greece	Gold...	Drachma	.1930	Gold: 5, 10, 20, 50 and 100 drachmas. Silver: 5 drachmas. Member of Latin Union; gold is the actual standard.
Haiti	Gold...	Gourde	.9647	Gold: 1, 2, 5 and 10 gourdes. Silver: gourde and divisions. Currency: Inconvertible paper; exchange rate, approximately, $0.16.
India (British)	Gold...	Pound sterling*	4.8665	Gold: sovereign (pound sterling). Silver: rupee and divisions.
Italy	Gold...	Lira	.1930	Gold: 5, 10, 20, 50 and 100 lire. Silver: 5 lire. Member of Latin Union; gold is the actual standard.
Japan	Gold...	Yen	.4985	Gold: 5, 10 and 20 yen. Silver: 10, 20 and 50 sen.
Liberia	Gold...	Dollar	1.0000	Currency: Depreciated silver token coins. Customs duties are collected in gold.
Mexico	Gold...	Peso†	.98	Gold: 5 and 10 pesos. Silver: dollar‡ (or peso) and divisions. Mexican exchange rate fluctuating and uncertain.
Netherlands	Gold...	Florin	.4020	Gold: 10 florins. Silver: 2½, 1 florin, and divisions.
Newfoundland	Gold...	Dollar	1.0139	Gold: 2 dollars ($2.027).
Norway	Gold...	Crown	.2680	Gold: 10 and 20 crowns.
Panama	Gold...	Balboa	1.0000	Gold: 1, 2½, 5, 10 and 20 balboas. Silver: peso and divisions.
Paraguay	Silver.	Peso	.5439	Currency: Depreciated paper, exchange rate 1550 per cent.
Persia	Silver.	Kran‡‡	.1002	Gold: ½, 1, and 2 tomans ($3.409). Silver: ¼, ½, 1, 2 and 5 krans.
Peru	Gold...	Libra	4.8665	Gold: ½ and 1 libra. Silver: sol and divisions.
Philippine Islands	Gold...	Peso	.5000	Silver peso: 10, 20 and 50 centavos.
Portugal	Gold...	Milreis	1.0805	Gold: 1, 2, 5 and 10 milreis.
Roumania	Gold...	Leu	.1930	Currency: Inconvertible paper; exchange rate, approximately, $0.9394.
Russia	Gold...	Ruble	.5146	Gold: 5, 7½, 10 and 15 rubles. Silver: 5, 10, 15, 20, 25, 50 and 100 copecks.
Santo Domingo	Gold...	Dollar	1.0000	....
Servia	Gold...	Dinar	.1930	....
Siam	Gold...	Tical	.3709	....
Spain	Gold...	Peseta	.1930	Gold: 25 pesetas. Silver: 5 pesetas. Valuation is for the gold peseta; currency is silver circulating above its metallic value, approximately, $0.20.
Straits Settlement.	Gold...	Pound sterling§	4.8665	Gold: sovereign (pound sterling). Silver: dollar and divisions.
Sweden	Gold...	Crown	.2680	Gold: 10 and 20 crowns.
Switzerland	Gold...	Franc	.1930	Gold: 5, 10, 20, 50 and 100 francs. Silver: 5 francs. Member of Latin Union; gold is the actual standard.
Turkey	Gold...	Piaster	.0440	Gold: 25, 50, 100, 250 and 500 piasters. 100 piasters equal to the Turkish £.
Uruguay	Gold...	Peso	1.0342	Gold: peso. Silver: peso and divisions.
Venezuela	Gold...	Bolivar	.1930	Gold: 5, 10, 20, 50 and 100 bolivars. 5 bolivars.

* The sovereign is the standard coin of India, but the rupee ($0.3244⅓) is the current coin, valued at 15 to the sovereign.
† Seventy-five centigrams fine gold.
‡ Value in Mexico, $0.4985.
‡‡ The Gold Kran $0.0959.
§ The current coin of the Straits Settlements is the silver dollar issued on Government account, and which has been given a tentative value of $0.5678.

CONTENTS OF VOLUME XXV

Special Chapters

INTRODUCTION

Mineral Industry aims to present such information, both statistical and general, as will meet the ordinary requirements of those interested in mining and metallurgy, either directly or indirectly. Each branch of the industry is taken up in a separate article, arranged alphabetically, and each article is a review of production, trade conditions, and industrial and technical progress during the past year, presenting also the compilations of previous years for comparison. It would of course be impossible to give sufficient detail for the special investigator in any one subject. In such cases the volume is suggested as a valuable starting point, giving as it does a survey of the field and containing numerous references which can be followed up for fuller information as desired. In many cases a bibliography is appended to the article to assist in such a purpose. But for most uses the data presented will, we believe, be found sufficiently complete, whether the articles be considered as interesting discussions or as valuable purely for reference. For the latter use the index is designed to assist as far as possible, but the articles will be found to contain a large number of briefly mentioned facts of which it would be impossible to list all in the space available for an index, which is quite natural in a book of compilation.

In touching on the scope of the volume it is well to point out that it is intended to cover foreign fields and is also for use in foreign countries. However, it is difficult at all times both to obtain as much knowledge of foreign industries as of domestic, and also to be sure of using properly what information is obtained. Needless to say this difficulty has been multiplied in the last three years. We hope some day to be able to catch up with our foreign data; for the present we must be content to present as much as we can, realizing that whatever is available has an added value. Many countries still offer considerable data, but from Germany, Austria-Hungary, France and Belgium there is almost nothing.

A number of mineral industries, particularly those connected with the pottery and building trades, are so widely scattered that their treatment is beyond the scope of a general report of this kind. A few industries relating to manufactured material are included, where the production of the manufactured material is closely associated with that of the raw material, or where it is replacing to a considerable extent some natural material, *e.g.*, coke and cement.

The source of the material is of four classes: first, official reports of various governments; second, the work and publications of the United States Geological Survey; third, the columns of the technical press, United States and foreign; fourth, the personal knowledge and correspondence of the individual contributors.

The Editor is most grateful to contributors, who have given generously of their valuable time and whose work in most cases has been particularly deserving of appreciation this year on account of the press of other business. The Editor also desires to record his appreciation of the hearty coöperation of the Assistant Editor, Mr. Allison Butts.

We owe special acknowledgment to the columns of the following periodicals: *Engineering and Mining Journal*, *Mining and Scientific Press*, *Metallurgical and Chemical Engineering*, *Coal Age*, *Iron Age*, *Salt Lake Mining Review*, *Mining and Engineering World*, *Mining Journal*, *Mining Magazine*, *Canadian Mining Journal*, and *South African Mining Journal.* Such articles appearing in the periodicals as are considered most important for the case in hand are either abstracted or presented in reduced form, or in a few cases printed in full, always with the intention of noting the source either in the text or as a foot-note.

The make-up of the volume is similar to that of preceding volumes. The statistical tables at the end are made up from the official reports of the various countries. As these are often a year or more behind, the tables are completed to date, so far as possible, with unofficial figures. This will undoubtedly increase the value of the tables, even though some of the figures given are only approximately correct. Unofficial figures in the tables are given in full-face type to distinguish them from the official figures, or the source is otherwise noted.

As indicated on the title page, this volume is a supplement to Volumes I–XXIV, but at the same time it is more than a supplement. It not only adds the data for the year 1916, but also gives corrections of the figures incorporated in previous volumes. Hence, it is important in using Mineral Industry always to use the latest volume, even for figures for previous years, in order to get the benefit of these corrections, except, of course, in the case of the less important statistics, which are not carried from year to year, but are given only once.

G. A. Roush.

South Bethlehem, Pa.
July 16, 1917.

THE MINERAL INDUSTRY

1892–1916

By G. A. Roush

With this issue The Mineral Industry celebrates its silver jubilee, and in closing 25 years of active service to the mining and metallurgical industries, it is fitting to look back over these years and briefly to summarize some of their more striking developments.

At the outset, let us quote a few paragraphs from the preface of Volume 1 of the series, showing the causes which led to the inauguration of this series of annual volumes.

"This volume is a result of the development of the annual statistical numbers of the *Engineering and Mining Journal*, and owes its existence to the appreciation with which these statistics have been received by business men, by experts, and by others interested in the mineral industry throughout the world.

"The modern newspaper has made promptness in furnishing information not only familiar but indispensable to the man of affairs, and accurate and timely statistics have now become absolutely necessary for the intelligent direction of industry, trade, and legislation. The collection of such statistics in an industry which extends over the face of the entire globe is, however, a work so vast and difficult that it has hitherto been considered impossible except through the unlimited resources of governments; and as the machinery of government is not adapted to the rapid attainment of results, the statistics of the mineral industry have been so tardily collected and published in all countries, that their value has been greatly impaired. . . . For many years the *Engineering and Mining Journal*, as the leading representative of this great industry, has accumulated vast stores of statistical information relating to it, and has greatly improved the machinery for the collection of statistics. . . . The universal appreciation of the work done by the *Engineering and Mining Journal* called for its extension, and consequently in this initial volume there are given, for the first time, the statistics of substantially all the minerals and metals produced in the United States and in many other countries for the full year 1892, and often from the earliest times. This series of annual volumes it is intended shall, in due time, cover the entire mineral industry of the world, giving its statistics, its technology, and its trade, each succeeding volume not repeating the data given in previous issues, but supplementing them, and carrying forward the current history of the industry almost to the day of publication. . . .

"It is the object of this volume to summarize the facts which show how such results are accomplished; to photograph, as it were, from time to time, the condition of the several departments of the mineral industry in various parts of the world, placing within the reach of all the information that intelligence can apply to the reduction of cost in producing and marketing the useful minerals and metals and in promoting the welfare of those engaged in this industry. In every country this information will enable those who legislate for and those who administer this industry to do so with an intelligent appreciation of the conditions affecting it in its department, and widely disseminated, will promote the national prosperity."

Such were the circumstances that led to the inauguration of this series of volumes and how thorough was the foresight of the originator of the series is well shown by the fact that the editorial policy of the publication still remains almost unchanged after 25 years, as can be seen by comparing the present volume with the earliest ones in the series, and by comparing these statements from the first volume with the corresponding statement of policy in the Introduction to the present volume.

General Progress

In glancing through the first volume, we find many statements and discussions that in the light of present day developments are very interesting and in some cases amusing, as no doubt many of the discussions

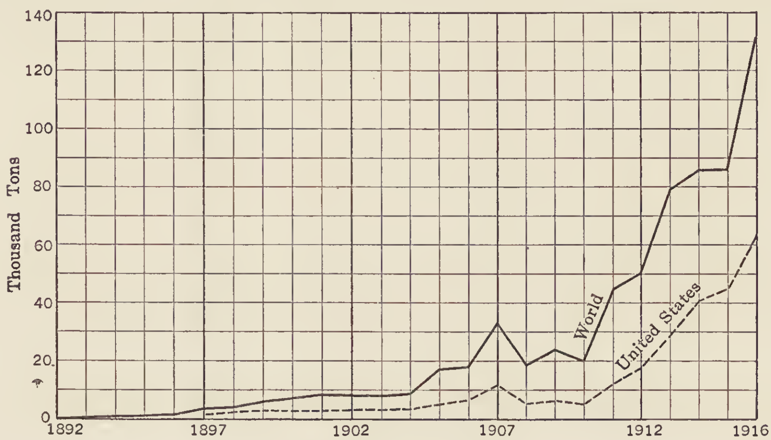

Fig. 1.—Aluminium production.

in the present volume will appear to the reader of a quarter of a century hence.

For example, attention is called to the enormous developments that had been made in the 5 or 6 years preceding in the metallurgy of aluminium, emphasizing the fact that the price of the metal had been brought down to as low as 50 cts. per lb. and the production for the year, in the United States, was almost 300,000 lb., and the world's production almost 500 metric tons. The article closes with the statement, "It is doubtful if the further prosecution of the electrical methods, by which alone aluminium is now made, will bring the cost of it to the point at which it will become a prominent metal, unless they proceed along the line of direct reduction. Even here it is by no means certain that they can make it cheap enough. . . . While the electrical reduction methods are not to be condemned, those who seek by other means to make cheaper aluminium should be encouraged." Compare this with present conditions, with a United States production of 63,000 metric tons, a world's production of 132,500 tons and a production cost that has been estimated as low as 10 cts. per lb.

It is interesting to note that the coal production in the United States to-day is equal to the world's production as reported in Volume I. The United States was then second in production with Great Britain leading, while the United States now leads with a production almost equal to the

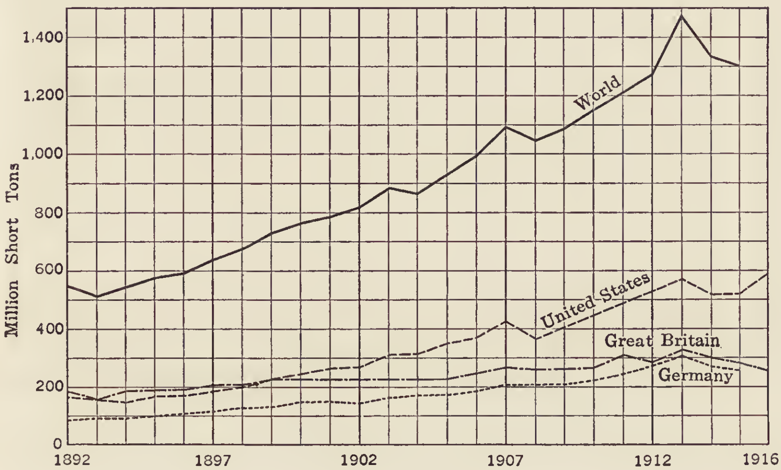

FIG. 2.—Coal production.

combined production of her two nearest competitors, Great Britain and Germany. These two for several years past have ranked very close together, with Great Britain slightly in the lead, while 25 years ago Great Britain's production was double that of Germany. Although these three great producers have changed order in the tables and have all seen enormous increases of production of from nearly 100 to over 300 per cent. in the course of 25 years, the production of all three still bears almost exactly the same ratio to the world's production, namely, slightly over 80 per cent. of the total.

During the period under review, the world's copper production has more than trebled, while the production of the United States has increased to 6 times its former amount. The United States has always led in production, but during the time has increased from 45 per cent. to almost 65 per cent. of the total. Twenty-five years ago Spain and

Portugal came second, Chile third, Japan fourth and Germany fifth; the order now stands Japan second, Chile third, Mexico fourth, Canada fifth.

With gold and silver the figures are no less interesting. The gold production of the world has quadrupled while that of the United States has trebled. Twenty-five years ago the order of production was United States, Australia, Russia, Africa. At present it is Africa, United States,

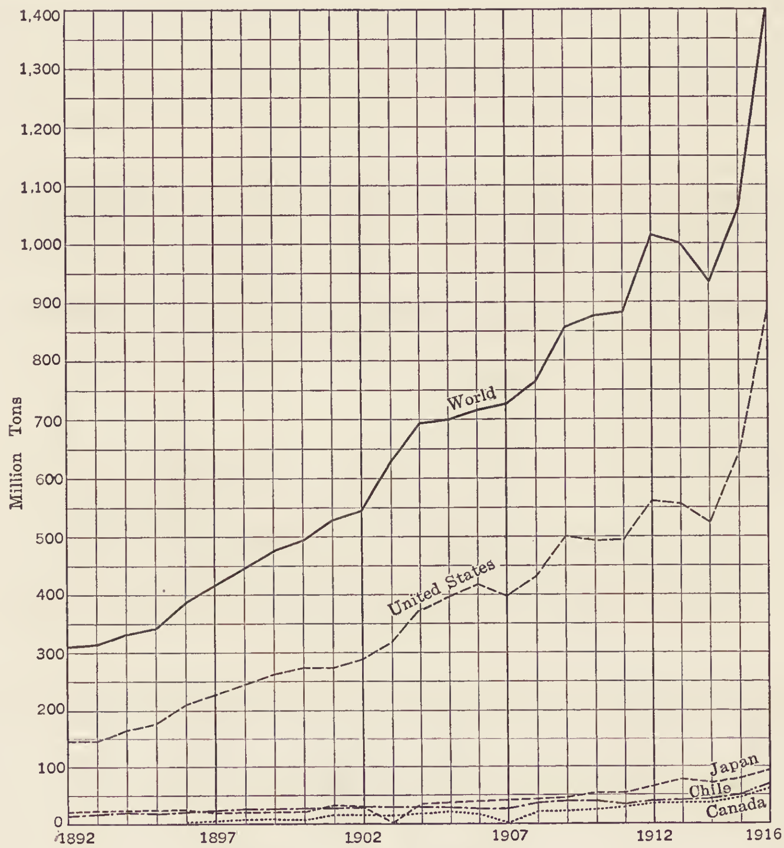

Fig. 3.—Copper production.

Australia, Russia. The African production, due to the enormous developments on the Rand, has increased to over 14 times its previous value, and now leads with about double the production of the United States, its nearest competitor.

The silver, up to 1911, had increased about 60 per cent., but in the last 5 years there has been a rapid decline, due to the revolutionary activities in Mexico, the heaviest producer, so that at present the production stands only about 10 per cent. higher than 25 years ago. Since the price has dropped faster than the production increased, the world's production of silver in 1915 was worth only about one-half as much as the production of 25 years ago. The rise of prices during the last year will, however,

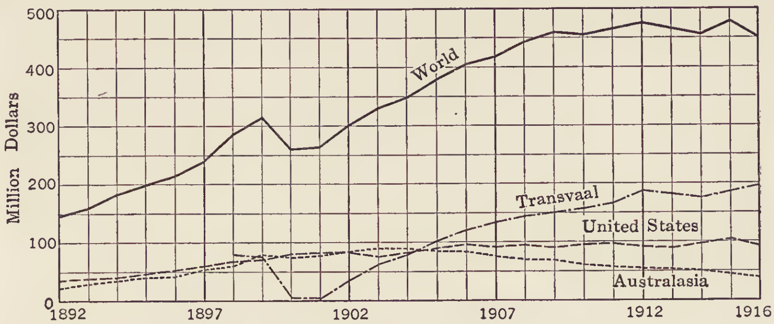

Fig. 4.—Gold production.

partly eliminate this discrepancy in value, and will reduce the deficiency in value from 50 to about 35 per cent. The United States started with a lead of 50 per cent. over Mexico, the holder of second place, and ended with a production about double that of Mexico; but from 1902 to 1912

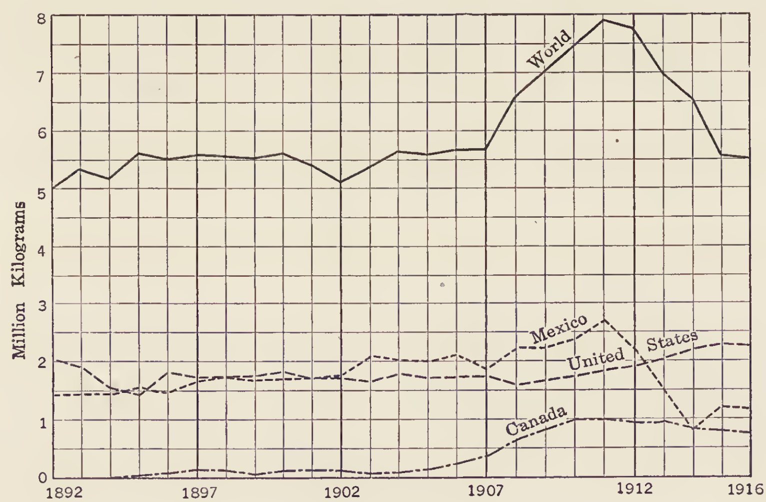

Fig. 5.—Silver production.

the Mexican production considerably exceeded that of the United States. The latter has shown an increase of about one-eighth, while Mexico has suffered such a decline as not only to wipe out the heavy lead with which she had held first place for 10 years, but has even pulled her considerably below her production of 25 years ago. Formerly Bolivia held third place, and Australia fourth. Mexico's position in second place is now being threatened by Canada, which formerly was far down the list, while Peru holds fourth place, and Australia has dropped behind Japan and Spain.

The production of iron ore in the United States now is about four times the production of a quarter of a century ago, and the pig-iron production has increased in about the same ratio, while the pig-iron production of the world has increased to about three times its former amount. The order of producers is now United States, Germany, Great Britain, France, and Russia, with Austria-Hungary and Belgium practically tied for last place in the list of producers of more than 1,000,000 tons per year.

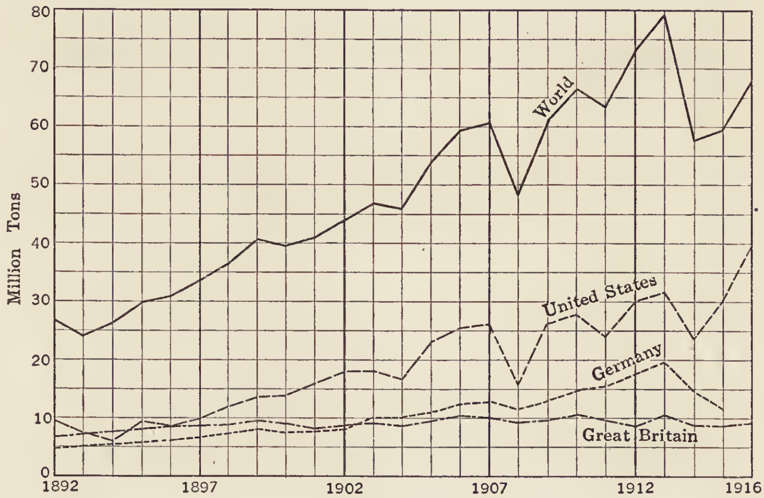

FIG. 6.—Pig-iron production.

The previous order was United States, Great Britain, Germany, France, Austria-Hungary, Russia and Belgium, with the last three all below the million-ton mark. Pig-iron production in the United States to-day is at a rate approximately a third greater than that for the entire world 25 years ago. It is true that the United States was in the lead in production then, but Great Britain was a close second, and the German production was over 50 per cent. of the United States production. To-day the United States production is approximately 50 per cent. of the world's production, or, in other words, is equal to that of all the rest of the world put together.

The steel production naturally follows closely the production of pig-iron, and the order of production for the various countries is the same for steel as for pig-iron, both at the beginning and end of the period under review. Due, however, to the development of processes which permit the use of greater proportions of scrap and waste material in the manufacture of the steel, and to the development of processes with higher percentage

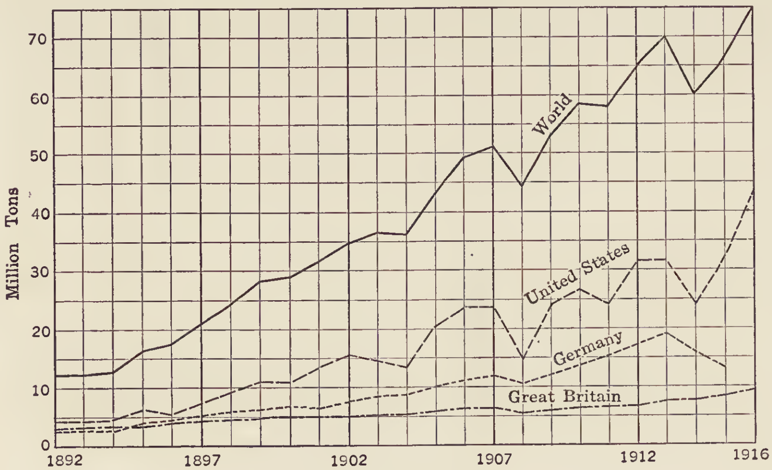

Fig. 7.—Steel production.

yields of finished steel on the raw material used, the total production of steel has grown faster than that of pig-iron, and is now over five times what it was 25 years ago. And where the United States produced only

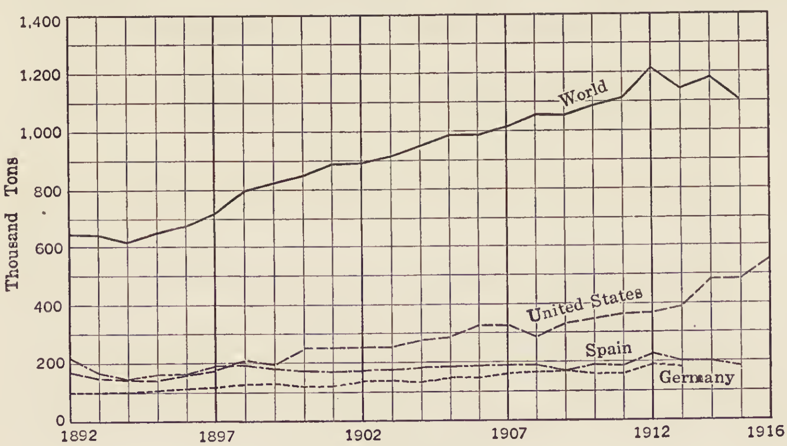

Fig. 8.—Lead production.

a little over one-fourth of the former total, it now produces half, and the production of the United States has increased eight-fold.

During this period, the processes used in the manufacture of steel have undergone a remarkable transformation. In 1892, almost 84 per cent. of the steel production of the United States was made in the Bessemer converter, and 14 per cent. in the open-hearth furnace. The corresponding proportions to-day are 26 per cent. in the converter and 74 per cent. in the open-hearth.

Lead production in the world during the past 25 years has approximately doubled. The ranking of producers at present is: United States, Spain, Germany, Australia and Mexico, all normally producing over 100,000 tons annually, but this figure has not been reached in Mexico during the last few years on account of the curtailment of production due to revolutionary activities. The former order of producers was the same as at present, except that Mexico was ahead of Australia. The heaviest increase was in the United States, amounting to about 260 per cent.

The enormous developments in the steel industry have demanded a proportionate increase in manganese production. The world's produc-

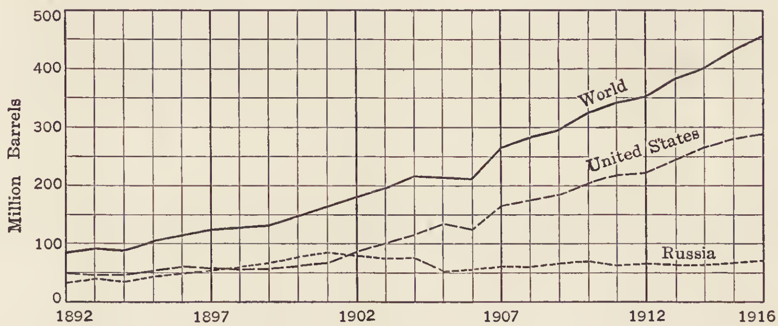

Fig. 9.—Petroleum production.

tion is now about seven or eight times what it was 25 years ago, and there are now three countries, India, Russia and the United States, with productions ranging from two to three times the world's production of 25 years ago.

The petroleum production of the world during the period has increased five-fold. In 1892, the producers showing more than 1,000,000 bbl. per year were the United States and Russia, together accounting for 97 per cent. of the world's production. The present producers of more than 1,000,000 bbl. per year are, in order of production, United States, Russia, Mexico, Dutch East Indies, Roumania, Galicia, India, Peru, and Japan. The United States now contributes 64 per cent. of the world's production, as against 57 per cent. 25 years ago, and now stands at about six times its former production. The Dutch East Indies, Peru, Argentina, Trinidad, Mexico and Egypt have entered the field as large producers during the period and now account for one-eighth of the total production.

The world's sulphur production is obtained almost entirely from Italy and the United States, with smaller amounts from Japan and Spain. Twenty-five years ago Italy was the producer of over 90 per cent. of the world's supply, with most of the remainder coming from Japan. Consumption was on the increase, and the Italian production grew rapidly, reaching a maximum in 1905, when the production was nearly double that of 1892. Production in quantity in the United States began in 1903 and this soon reacted on the Italian production, which declined to about 50 per cent. of the total.

Sulphur production during the 25 years has doubled, but pyrite production has more than trebled. Formerly, France led in production,

Fig. 10.—Sulphur production.

followed by Portugal, Germany, United States and Spain, all producing over 100,000 tons annually. The producers of that quantity at present are as follows: Spain, Norway, Portugal, United States, Italy, France, Germany, Canada, Russia, Japan and Hungary. Of all, Spain has shown the greatest increase, with Norway second. The Spanish production has jumped from 10 per cent. of the total to nearly 25 per cent., and the Norwegian from 6 per cent. to double that proportion. The United States production has just about kept pace with the total production.

The tin production of the world has, in the quarter of a century, almost doubled. Malaya still contributes a large share of the total, but has dropped from over 50 per cent. almost to 40 per cent. England long held second place, but now Bolivia takes it with almost 20 per cent. of the total, where formerly she was at the end of the list with

3 per cent. Banka still retains third place, having increased somewhat more rapidly than the totals. Australia and Billiton have both declined, the former the more seriously.

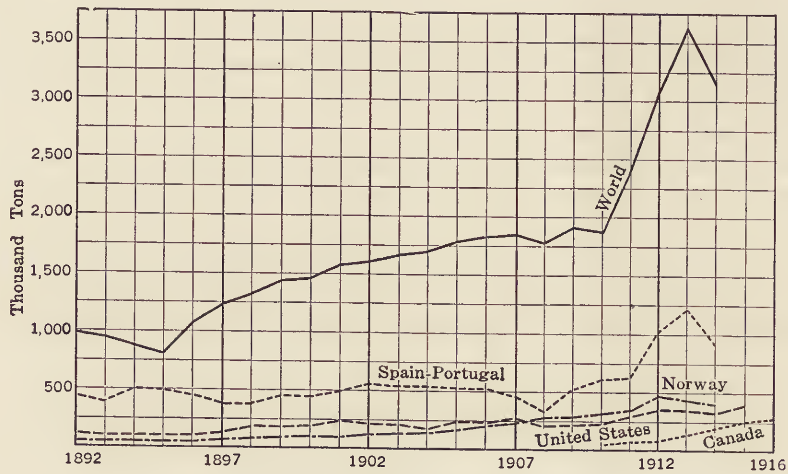

Fig. 11.—Pyrite production.

Tungsten is a metal that has seen almost its entire commercial growth within the period under review, and most of that within the last few years. The production of tungsten ores in this time has increased in a ratio of almost 50 to 1, two-thirds of which has been within the last 5

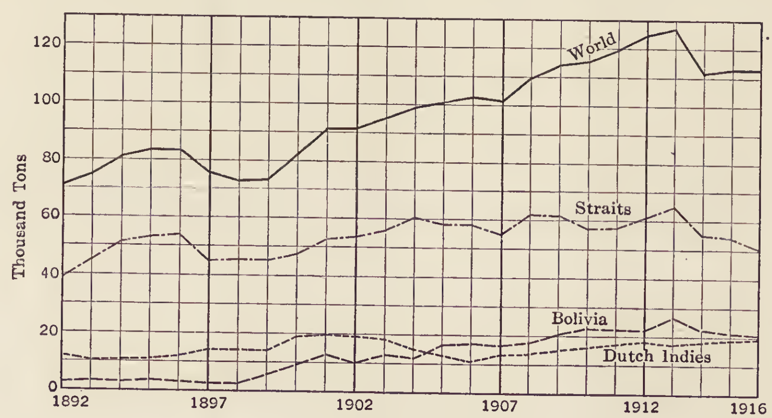

Fig. 12.—Tin production.

years. In the present production, the United States accounts for 35 per cent. of the total, Burma 22 per cent., Portugal 8 per cent., Australia 7 per cent., and Japan 6 per cent., all producing over 1000 tons annually.

Zinc production in the past 25 years has about trebled. Most of the leading zinc producing countries have been disturbed by the war to such an extent that recent figures are not available for comparison, but from

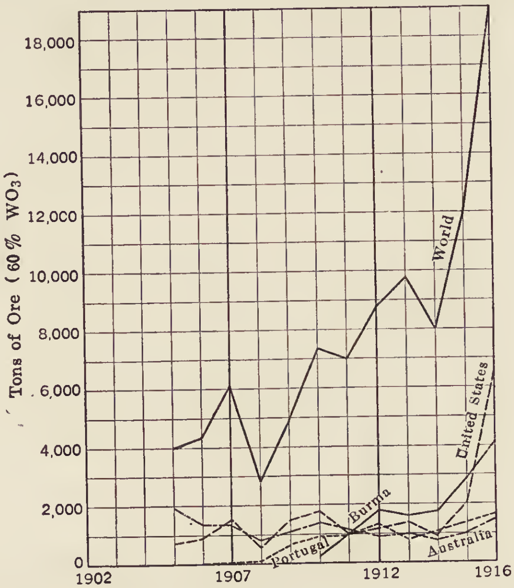

FIG. 13.—Tungsten production.

the latest data available, the United States was the leading producer with Germany second, Belgium third, France fourth and Great Britain fifth. The former order was Germany, Belgium, United States, Great Britain,

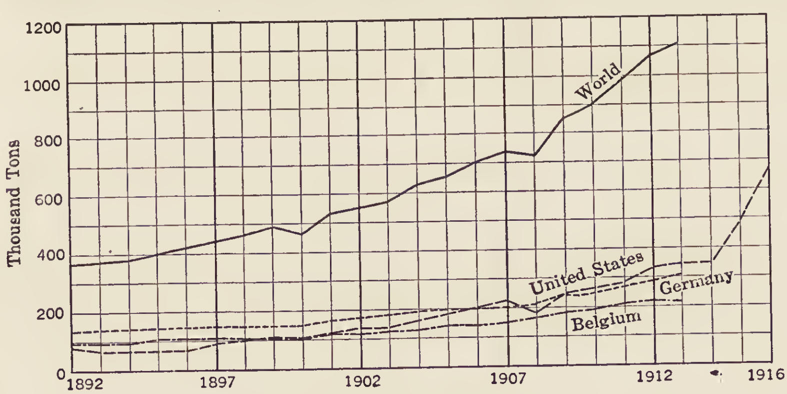

FIG. 14.—Zinc production.

France. The United States has increased its production to eight times its former amount, and has increased its proportion of the world's output from 20 per cent. to about 60 per cent.

It is of course absolutely impossible to make anything like a direct comparison between conditions now and 25 years ago, because now everything is on an abnormal basis. Some industries are swelled to beyond all semblance of their normal proportions by the extraordinary demands of war, while others are severely handicapped because of the disturbance of raw materials and markets, and the serious difficulties encountered in shipping, difficulties which are not by any means confined to trade with belligerent countries, but extend also to the neutral countries and, in a large measure, to purely domestic shipping as well. However, in spite of all of the necessary readjustments, the period of the war has been, to most of the mineral and metallurgical industries, one of unparalleled prosperity. This is particularly true with aluminium, copper, iron and steel, tungsten, and zinc, which on this account have come to be classed under the heading of "war metals."

Future Developments

What is in store for the future is difficult to foresee, but whatever may be the eventual outcome of the present conflict, it seems certain that the mineral and metallurgical industries will be called on to continue production to their utmost capacities, in the work of restoration, and this will extend over a period of several years. It is to be expected that there will be somewhat of a slackening in speed after the conclusion of the war, for, however pressing may be her needs, Peace can never be the exacting taskmaster that War is; this slackening will be simply a logical outcome of the conditions, but it should not be of such proportions as to cause a serious slump in any industry as soon as the war demands are satisfied. On the contrary, manufacturing plants will be able to relax from the strain of war production and settle down to the fulfilment of the demands of peace and reconstruction at practically their normal capacity at the time. Of course it is not going to be possible after the war to keep the production curves of the various materials going on up at the precipitous angle they have assumed during the war, for demand in many lines now is far above normal and is still increasing, but the normal course of the world's progress will soon bring it to a point where it can absorb these enormous productions, and it is quite possible that the demands of reconstruction will absorb the excess over a sufficient period of time to permit this condition to be realized, so that at the worst, all the industries will suffer will be a period of a few years with little or no increase beyond the point at which they were at the close of the war, rather than a serious break in production and values.

The titanic forces of the present struggle are rapidly bringing to a head many conditions that normally would have required years of slow development. New industries are born over night and grow to a real semblance of maturity in weeks instead of years. Plant productions increase by leaps and bounds, doubling and trebling within the year under the impetus of an all-absorbing demand and an unprecedented price. New machinery and processes are developed and invention is stimulated in all branches of industry.

One of the interesting points in this connection is the constantly growing demand for the general adoption of the metric system of weights and measures, both in the United States and in Great Britain. We quote the following from the introduction to Volume I of this series, to the sentiment of which we can as heartily subscribe to-day as the day it was written.

"It is with the very greatest regret that we have been obliged in this work to use other than the metric system of weights and measures, which are now legalized in nearly every civilized country and should be universally adopted. The necessity of conforming to custom and popular prejudice in a work so extensive as this explains the use here of the nightmare of weights and measures which, as a relic of barbarism, survives and is used in all English-speaking countries as 'the English system.' We have, however, where possible, reduced the number of varieties of measures used. . . . All foreign statistics are given in this work in metric system as well as in the customary weights." . . .

On the whole, it has usually been considered that England was more "sot in her ways" in this regard than the United States, but if the following editorial from a recent number of the *Mining Magazine*, of London, is any criterion of present English opinion on the subject, it is to be feared that America is losing out in the race.

"While English engineers and trading houses are inclined to the advocates of reform in our system of weights and measures and the adoption of the metric system, the American manufacturers are organizing a strong opposition to any proposed interference with the present units. The objection to change is based on the cost of preparing new standards of patterns and materials, and on the implied loss of old factors and data of work and costs accumulated from experience both in the factories and in the text-books. A society called the American Institute of Weights and Measures has been formed to protect and conserve the present units, and to combat the 'insidious methods employed to foist the metric system on the country.' If they had not said so themselves, we should not have believed that there were so many crusted tories and last-ditchers in America."

International Relations

Since the opening of the European war the latter part of July, 1914, with its accompanying commercial disturbances, there has been a great deal of discussion in this country concerning the possibility of making the

United States independent of foreign supplies in order to avoid future difficulties of this kind. This of course does not mean that all imports are to be discontinued, but that attempts be made to furnish domestic supplies of basic materials, in order that a whole industry may not be handicapped by the lack of some one material on which the process of manufacture depends. On analysis, however, this proposition does not prove to be as simple as it seems on the surface, particularly with regard to the mineral industry, either for the United States or for any other country. And naturally, the smaller the country concerned and the more limited her resources, the more remote does any such possibility become. The discussion as here outlined is from the particular standpoint of the United States, but the arguments apply equally well, in a general way, to any of the other large mineral producing countries.

It follows from the natural course of human life and its needs that certain industries should be fundamental, and others secondary or in other words, that certain basic industries are concerned with the supplying of the prime necessities of life in their crudest forms, while the other industries are concerned with the modification of these crude forms through various stages of higher refinement, or with modifications of form, location, etc. Of these basic industries, probably none is more widely scattered over the face of the earth, more closely related to the general welfare and progress of the countries concerned and in fact more thoroughly universal than the mineral industry, with the single exception of agriculture. In no other industry is the influence of a single locality so widely felt as in the mineral industry. For years the world went to Ceylon for its graphite, to Sicily for its sulphur, to the Ural mountains for its platinum. A small district in the State of Arkansas furnishes the raw material for 65 per cent. of the world's supply of aluminium. Chile furnishes practically the entire world's supply of sodium nitrate and Germany has supplied such a larger proportion of the world's supply of potash that the limitations of production and exportation resulting from the disturbances of war have made a shortage of this most necessary material throughout almost the entire world. And carrying things to the opposite extreme, it requires almost a page to list the countries that produce important quantities of the ores of gold, silver, copper or iron.

Probably every country and every state on the face of the globe has within its borders valuable mineral resources of one kind or another, of greater or less importance. In many cases it is something that is merely of local interest and importance; in other cases, such as those mentioned above, the materials are of international importance. Dana classes ice as a mineral, but its use purely as a mineral substance is probably limited to its employment as a building material in the arctic regions. Southern

Indiana's Bedford limestone and Vermont's granite, however, while used for the same purpose, are naturally of incomparable wider application and value. When the production and use of any material is purely a matter of local interest, any knowledge or information concerning the industry involved in the production is also merely of local interest, but just as the breadth of the market and the scope of application of any material increases, so does the demand for information in regard to that material increase and the more general is the demand for the material itself, the more general is the demand for knowledge concerning the progress of the industries producing this same material in other localities; and on this demand for knowledge there can be placed no final limitation except one of degree; other factors, geographical or political, economic or social, are contributive, rather than determinative.

The Arizona copper producer is interested more in the Montana production than in that of Utah, not because it comes from Montana, but because it is a heavier competitor for the market for his output; but should the Utah production exceed that of Montana, Arizona's interest would follow the heavier producer, rather than a given locality. Europe is interested in the Chilean copper developments, not because they are in Chile, but because they promise an additional amount of metal available for import into Europe, and the interest would be just as great if the deposits were in Fiji, or Greenland.

As Kipling says, "The Colonel's lady and Julia O'Grady are sisters under skin." The laborer, the superintendent, the general manager, the New York capitalist, all have the same general interest, differing only in intensity and extent, depending on the contributing factors. The laborer makes his living from his work in the mines or smeltery, and wants to know how things compare in the mine where he works and in the other mines in the neighborhood. The superintendent compares conditions in his own working district with the adjoining districts. The general manager in charge of plants in different parts of the country, will consider matters on a still broader scope, and the capitalist will compare his holdings in this country with those in other countries. And so we have in every case, from whatever angle the question may be considered, an interest proportioned to the extent to which the individual is affected by the conditions within his own particular field of operations, as compared with other fields of similar work.

The general interest thus manifested and the demand thus created for knowledge of the progress of an industry in different localities is inseparably linked with the economic dependence of each country of the world on most of the other countries. That stage of civilization when the world was made up of a number of independent districts is long past. A given locality can no longer produce within its own confines everything that is demanded in the course of its life. In the first place, civilization has reached a point where it demands more than it has in the past; and in the second place, economic development and the law of the survival of the fittest has led to an age of constantly increasing specialization, which, aided by increasing ease of communication and transportation, has brought things to a point where we now find ourselves dependent for one thing or another on almost every district of the civilized world.

This dependence can be well illustrated as the average man looks around his own home. He no longer lives in a house of his own building, eats food of his own growing, cooked in vessels of his own making, and wears clothes of his own weaving. In the average man's house we now see aluminium which probably originated in Arkansas, or possibly in France, and which, in the course of manufacture demanded cryolite from Greenland. He reads a newspaper printed from type containing lead from Missouri, Idaho, Utah, or Mexico, and antimony from China. The asbestos pads on the kitchen stove came from Canada, and the polish on the stove from Korea, or possibly from Ceylon or Madagascar. The street in front of the house is paved with asphalt from Trinidad. The house is painted with a barium paint from Germany. He frequently uses as a medicine, iodine from Chile, and bismuth from Bolivia. Such steel as he uses comes mostly from the United States, but the furnace in which it was made required magnesite from Austria or Greece, and as the steel came from the furnace it was deoxidized with manganese from Russia, India or Brazil. To make his stove bright and cheerful, it is given windows which are glazed with mica from Canada or India. He gets his light at night from gas mantles made from monazite from Brazil or from electric globes, the tungsten filaments of which may have originated in the United States, but which are just as likely to have come from Burma or Bolivia. He uses nickel from Canada and tin from Bolivia or Malay. He fertilizes his lawn and garden with nitrate from Chile and potash from Germany. His wife cherishes an engagement ring bearing a tiny diamond from South Africa, set in platinum from Russia, and dreams of some time having a necklace of "real pearls" from the South Sea Islands. They eat off china from Germany, with silverware that might have come from almost anywhere, and after dinner he smokes a cigar that he fondly thinks came from Havana.

So close is this association of the various countries in a commercial way, that any factor that disturbs one country will disturb several, through its commercial relations with the others, and anything that disturbs several will disturb practically all. An indication of this condition is the unanimity with which the contributors to the technical press mention the effects of the present European war on the various industries that they happen to be discussing. Almost without exception, these industries have been considerably affected by the war. Some have been stimulated and some have been retarded and disorganized, but very few have remained unaffected.

These two factors, the individual interest in other localities supporting a given industry, and the interdependence of the various countries on each other for adequate supplies of certain materials, make necessary the dissemination of general information in regard to the status of the various industries from time to time. There are in the various states and countries certain organized agencies for the collection and distribution of such information, and the technical press gives a large amount of general information along these lines. But there is still room for considerable expansion along this line. Information should be fuller and more detailed, and should be made available more promptly.

It is not to be expected with the present broad development of all the various industries that any country of importance can become entirely independent of others in the matter of mineral production. It is possible to become partly so by the fullest development of the domestic resources, but absolute independence is impossible, because no one country, not even the United States nor Great Britain with all her colonial possessions, includes within its boundaries *all* of the almost infinite varieties of mineral products that are now demanded by our every day life.

Personal Coöperation

The prime requirement for the best development of domestic resources is a thorough knowledge of those resources. And for the best results, this knowledge must be well disseminated and not be confined to a few people in the immediate locality. In other words, every available source of material should be thoroughly advertised—not necessarily by paid advertising—but by proper publicity in the technical press, in order that the information may be readily available to all who are interested. This condition is at present only partly fulfilled, and there is room for considerable improvement.

And next in importance after a thorough knowledge of domestic conditions, is an equally thorough knowledge concerning the various foreign sources of any given material. This is of course more difficult to secure, and information is not nearly so plentiful as for domestic conditions, and usually the more remote the locality, the more meagre is the information. Many of the disturbances of the past 3 years in foreign supplies of materials would doubtless have been considerably lessened if importers had had a fuller knowledge of sources of materials. Too many had no information beyond their own particular source of supply. And in many cases the necessary information was very hard to secure.

All the evidence, then, points to the necessity of fuller information concerning both foreign and domestic supplies of materials. And since it seems impossible for any country to be minerally independent, let each at least exert a reasonable degree of care in the apportionment of its dependence, for the strain can be considerably lessened for all by a proper exchange of information. To this end, coöperation between the various agencies interested in the collection and dissemination of such information is to be encouraged and fostered to the utmost possible degree. And of course there must be some central agency for the final bringing together of the material from its various sources, and presenting it in a usable form. This is a service that The Mineral Industry has attempted to do for the mining and metallurgical industries for the past 25 years. The task has not been an easy one, but neither has it been a thankless one, as is evidenced in a number of ways with the appearance of each successive volume. And in turn, our thanks go out to all who have been of assistance, either directly or indirectly, in the production of the past volumes: to the various departments of our own and numerous foreign governments; to the representatives of the technical press; to private individuals and firms that have furnished valuable aid and information; and to the contributors, on whose shoulders has fallen the far from easy task of the actual preparation of the material.

The following list includes those who have contributed to more than one of the 25 volumes of the series, as indicated by the numbers following their names. In addition to these, a large number have contributed information for a single volume. The length of the list is explained by the fact that it includes not only those who have directly contributed articles for the volume, but also in many cases those who have contributed more or less general information for incorporation in different articles. The "List of Contributors" for a number of years was made up to include the names of a number of persons who did not contribute directly to the volume at all, but whose material was quoted from some one of the technical journals, in which it had originally appeared. This practice has now been discontinued, so that the list for several years past has included only those who have actually submitted the material under their names for use in the volume.

List of Contributors

Volumes 1–25

ABRASIVES

By J. Volney Lewis

In 1916, as in former years, the great bulk of abrasives for the metal-working industries has been supplied by imports of emery and corundum and by the two prominent classes of artificial products, silicon carbide and alumina. The small irregular mining operations in the Peekskill emery district of New York were again the only American source of natural abrasives.

The most marked tendency of the abrasive industry during the past decade has been the steady decline of emery and corundum with the increasing prominence, and eventually the dominance, of the artificial products. To this transformation several factors have contributed, chief among which have been the higher efficiency and the greater uniformity and dependability of the manufactured abrasives as compared with emery and corundum.

In the face of this competition Canadian corundum has practically disappeared as an important factor in the market. The supremacy of the artificial products has been further strengthened by the influences of the war: (1) in the great stimulation of the metal-working industries and the consequent extension of works, establishment of new plants, and the speeding up of production all along the line, thus creating a demand not only for greatly increased supplies, but also for the most reliable and efficient materials; (2) in the restriction and eventual exclusion from the markets of Turkish emery, hitherto the chief source of this material, coupled with the greatly increased difficulty and uncertainty of importations of the Grecian (Naxos) emery.

In spite of greatly increased demands, corundum from India has scarcely compensated for the reduced Canadian supply and Grecian emery has fallen far short of filling the gap of the Turkish product; and the continued importation of these materials in considerable quantities is doubtless in part attributable to their relative cheapness. Thus, the universal advance in prices has been steadily reflected in the decreasing imports of Turkish emery at higher and higher values, but Grecian emery came in at lower prices in 1916, and the value of corundum grains has also suffered decline with the increasing proportions of the Indian mineral.

The following table shows a comparison of the chief elements in the abrasive situation in the United States for the past decade. It should be pointed out, however, that there are omissions from this table, some of which have become increasingly important during the past 5 years. Thus, imports of emery and corundum manufactures to the value of $35,828 in 1916 are not included; further, to the artificial abrasives of domestic origin, which alone are shown in the table, should be added imports worth $940,219 in 1916. These additions give approximately the total bulk of abrasive business for the year, that is, the volume of materials of this class originating in or imported into this country. This total is not to be confused, however, with the consumption of abrasives in the United States, since products to the value of $4,276,178 were exported the same year.

NATURAL AND ARTIFICIAL ABRASIVES IN THE UNITED STATES[1]
(Short tons)

	Domestic.		Imported Emery and Corundum.	Total Mineral Abrasive.	Alundum, etc.	Carborundum, etc.	Total Artificial.	Per Cent. Artificial.
	Garnet.	Emery and Corundum.						
1906	4,650	1,160	17,829	23,639	2,166	3,113	5,279	18.3
1907	7,058	1,069	14,724	22,851	3,376	3,766	7,142	23.8
1908	1,996	669	9.922	12,587	1,580	2,454	4,034	24.3
1909	2,972	1,580	12,364	16,916	6,789	3,239	10,028	37.2
1910	3,814	1,028	33,576	38,418	6,705	5,354	12,059	23.4
1911	4,076	659	12,878	17,613	5,558	5,188	10,746	37.9
1912	4,947	992	19,425	25,364	6,633	6,021	12,654	33.3
1913	5,308	957	20,425	26,690	10,102	6,299	16,401	38.1
1914	4,231	485	14,457	18,968	10,419	5,411	15,830	45.5
1915	4,301	3,063	10,116	17,480	(e)11,000	5,460	16,460	48.5
1916	....	....	9,362	....	....	....	....	....

(e) Estimated.

Imports.—The great transformation that has taken place in abrasive importations—the exclusion of Turkish emery and the partial substitution of that from Naxos and the increase of Indian corundum to compensate for the heavy decline in the Canadian—has been referred to above. The following table shows a decrease of nearly 10 per cent. in crude emery,

IMPORTS OF CORUNDUM AND EMERY, 1914–1916[2]

	Corundum.		Emery.		Totals (Long Tons).
	Ore (Long Tons).	Grains (Pounds).	Ore (Long Tons).	Grains (Pounds).	
1914	246	1,120,147	12,662	761,674	13,703
1915	149	707,034	8,313	569,639	9,031
1916	112	1,428,284	7,511	220,605	8,359
Decrease (−) or Increase (+) Quantity	−37	+721,250	−802	−349,034	−672
Decrease (−) or Increase (+) Per Cent.	−24.8	+114.5	−9.6	−61.3	−7.4

Practically all emery and corundum grains imported in 1916 came from Great Britain, as did also most of the manufactures.

[1] Domestic natural abrasives, U. S. Geol. Surv.; artificial, MINERAL INDUSTRY. All reduced to short tons for comparison.
[2] Compiled from reports of the Bureau of Foreign and Domestic Commerce.

nearly 25 per cent. in crude corundum—in both cases following a still greater decline in the preceding year—a drop of over 60 per cent. in emery grains, but an increase of about 115 per cent. in corundum grains. This still leaves a net decrease of 7.4 per cent. in the total imports of emery and corundum in the form of ore and grains, following a total decrease of 34 per cent. in 1915.

The reversal in the emery situation owing to the war is clearly shown in the following table of imports of crude ore for the past 5 years, compiled and calculated from reports of the Bureau of Foreign and Domestic Commerce:

IMPORTS OF CRUDE EMERY, 1912–1916
(Years ending June 30)
(Long tons)

	From Turkey in Asia.				From Greece.				All Other.
	Tons.	Per Cent.	Per Ton.	Value.	Tons.	Per Cent.	Per Ton.	Value.	
1912	13,964	100.0	$17.22	$240,443	....	....	....	....	2
1913	18,367	96.9	17.27	317,224	....	....	....	....	597
1914	13,804	97.3	18.55	256,084	....	....	....	....	393
1915	3,923	54.5	19.79	77,641	3,259	45.3	$22.65	$73,817	12
1916	500	4.9	24.45	12,227	9,681	94.4	18.32	177,406	74

Concerning the absence of Grecian emery in 1913 and 1914, see "Emery Production in Greece" on a following page.

AVERAGE PRICES OF CORUNDUM AND EMERY GRAINS IMPORTED
(Years ending June 30)

	1912.	1913.	1914.	1915.	1916.
Corundum grains	6.01	4.50	5.48	4.80	4.48
Emery grains	4.72	4.04	4.01	3.97	4.05

The combined imports of corundum and emery in the forms of grains, ore, and manufactures for the years 1907–1916 are shown in the following table, together with the value of artificial abrasives imported since 1911.

IMPORTS OF CORUNDUM AND EMERY, 1907–1916[1]

	Grains.		Ore and Rock.		Manufactures, Value.	Artificial Value.	Total Value.
	Pounds.	Value.	Long Tons.	Value.			
1907	4,282,228	$186,156	11,235	$211,192	$15,282	....	$412,630
1908	1,735,366	89,702	8,084	146,105	15,592	....	248,399
1909	2,696,960	132,264	9,836	186,930	19,803	....	338,997
1910	2,311,464	106,570	28,948	509,661	13,527	....	629,758
1911	1,382,813	76,027	10,822	245,459	15,158	$49,617	386,261
1912	2,135,922	105,325	16,391	369,529	16,871	88,550	580,275
1913	2,496,372	114,786	17,123	342,809	16,704	190,290	664,589
1914	1,781,821	79,989	12,909	280,876	22,581	233,799	617,245
1915	1,276,673	56,254	8,462	197,303	18,092	255,474	527,123
1916	1,648,889	88,049	7,623	113,176	35,828	547,948	785,001

[1] Statistics for 1907–1913 from the U. S. Geol. Surv.; for 1914–1916 from Bureau of Foreign and Domestic Commerce.

The latter come chiefly from Canada, France, and Switzerland. Canada shows increasing preponderance in the last 2 years, furnishing 64 per cent. of the total in 1915–1916.

The total imports of crude corundum for the fiscal year ended June 30, 1916, comprised 17 tons from South Africa. Grains in relatively small amount came from Canada and in greatly increased amount from other countries, chiefly from Scotland (Indian corundum). The following table shows a comparison in the main between these two sources.

CORUNDUM IMPORTED FROM CANADA AND OTHER COUNTRIES[1]
(Years ending June 30)

	Ore and Rock.				Grains.			
	Canada.		Other Countries.		Canada.		Other Countries.	
	Long Tons.	Value.	Long Tons.	Value.	Pounds.	Value.	Pounds.	Value.
1911	424	$51,533	413	$11,507	1,566,100	$79,979	30,440	$1,133
1912	573	71,971	8	687	624,700	37,706	32,329	1,756
1913	421	61,953	120	16,448	1,872,500	83,275	65,303	3,912
1914	168	23,970	126	15,802	659,200	40,767	454,851	20,259
1915	149	21,136	34	2,565	607,500	31,464	223,844	8,450
1916	....	....	17	633	38,500	2,580	619,326	29,891

IMPORTS OF SCOURING AND POLISHING ABRASIVES, 1916
(Bureau of Foreign and Domestic Commerce)

Pumicestone, unmanufactured, 7627 long tons	$68,200
Pumicestone, manufactures	48,667
Rottenstone and tripoli	104,837
Total	$221,704

The pumicestone comes chiefly from Italy (Lipari Islands), with small amounts from Greece and the Canary Isles. Rottenstone is practically all from England. Formerly considerable amounts came from Germany.

Exports.—Abrasive materials of all kinds were exported in 1916 to the value of $4,276,178, as against $2,604,217 in 1915, an increase of 64.2 per cent. Exports of abrasive wheels increased 86.6 per cent. and constituted nearly half the total value.

ABRASIVES EXPORTED FROM THE UNITED STATES[1]

	1913.	1914.	1915.	1916.	Increase, Per Cent.
Wheels, emery and other	$731,297	$572,218	$1,200,421	$2,240,227	86.6
All others	1,551,892	1,123,505	1,403,796	2,035,951	45.0
Totals	$2,283,189	$1,695,723	$2,604,217	4,276,178	64.2

The following table shows the destination of the principal exports for the two fiscal years ending June 30, 1915 and 1916, from which it is seen

[1] Bureau of Foreign and Domestic Commerce.

that the chief increases have come from exports to Great Britain, Canada, France, Russia, Italy, and Norway.

DESTINATION OF ABRASIVE EXPORTS FROM THE UNITED STATES
(Years ending June 30).

	Wheels.		All Other.		Totals.	
	1915.	1916.	1915.	1916.	1915.	1916.
Great Britain	$326,076	$647,360	$437,636	$636,296	$763,712	$1,283,656
Canada	57,752	220,228	174,792	367,564	232,731	587,792
France	121,003	270,922	40,215	103,108	161,218	374,030
Russia	39,304	174,492	9,808	71,338	49,112	245,830
Italy	9,054	99,722	27,128	72,212	36,128	171,934
Australia	31,987	31,723	78,821	61,989	110,808	93,712
Denmark	17,505	12,664	66,175	77,003	83,680	89,667
Japan	43,431	27,910	18,997	46,412	62,428	74,322
Norway	1,287	11,443	15,652	39,539	12,939	50,982
Sweden	35,888	36,804	31,809	10,803	67,697	47,607
Netherlands	3,044	14,587	21,568	7,387	24,612	21,974
All others	14,859	82,410	144,449	209,442	153,308	291,932
Totals	$736,879	$1,630,265	$1,065,369	$1,703,073	$1,802,242	$3,333,338

Emery Production in Greece[1]

Emery, a mixture of dark granular corundum and other minerals, chiefly magnetite, is found in beds in various islands of Greece, but the only mines are on the island of Naxos in the Cyclades group. The mineral is a monopoly of the Greek Government, the sale of all Naxos emery being under the supervision of the Ministry of National Economy. In the world demand for this natural abrasive the United States takes a prominent part.

The product of the Naxos mines for 1915, delivery of which was to be made in the year 1916, was estimated at 15,000 metric tons of 2204.6 lb. each. Applications for about 70,000 tons had been filed to date (April 3). In the past distribution has been made on the basis of the order of application. There appears to be now a disposition to alter this arrangement, but no positive steps looking to this end have as yet been taken.

The world's production of emery stone has been estimated at 100,000 tons per annum; of this quantity Greece produces in normal times perhaps 15 per cent. The largest center of production is Asiatic Turkey. A fair proportion of the Greek product is shipped into Turkey and finds its way to market together with the product of Asia Minor.

The beds at Naxos are worked by the inhabitants of the island, who stoutly maintain that the mines are their property, and in practice at least this contention is admitted by the Government. No outsider, therefore, even though a Greek subject, is allowed to work in the mines;

[1] *Comm. Rept.*, April 29, 1916 and Aug. 22, 1916 (Abstract).

the inhabitants, however, reserve the right to employ outside labor should they see fit to do so. The ore extracted by this outside labor is for the account of the villagers. After extraction the mineral is transported to the seashore at either Lyonna or Moutsouna, where delivery is made to officials of the Ministry of National Economy, who pay the villagers. Government warehouses for the storage of emery are to be found at Syra. The contract for transportation of the mineral to the warehouse is given to the lowest bidder, the contractor being required to keep in the warehouse a minimum of 3000 metric tons. The Government at present pays 10 drachmas ($1.93) per metric ton for the transport from Naxos to Syra, including shipping expenses at Naxos and weighing, landing, and storage charges at Syra.

The present prices for emery, established by royal decree, represent an advance of about 30 per cent. over the prices prevailing in 1913. Delivery is made to the buyer at Syra. All expenses for weighing, cleaning, lighterage, and shipping are for the buyer's account, and average 3 francs (58 cts.) per ton. The maximum quantity that the Government can deliver per day is 250 tons. American firms wishing to secure a stock should appoint an agent, clothe him with full power, and arrange with him concerning the deposit required to be made when an application is approved.

Emery does not appear among the declared exports from Greece to the United States either in 1913 or 1914; more than 11,000 tons were declared for shipment to American ports in 1915. The apparent absence of exports of this ore to the United States for 1913 and 1914 is misleading, as certain shipments were undoubtedly made, but were merged into exports of Asia Minor emery and included in figures of exports through the port of Smyrna.

Corundum Production in Canada

Only the Burgess mine, in Carlow Township, Hastings County, Ontario, reported activity in 1915, when the production was 262 tons and the average value $126.48 per ton. In 1916 only 67 tons was pro-

PRODUCTION OF CORUNDUM IN CANADA, 1910–1916[1]

	Tons.	Value.	Average per Ton.
1910	1,870	$171,994	$91.98
1911	1,471	147,158	100.04
1912	1,960	233,212	119.00
1913	1,177	137,036	116.42
1914	548	65,730	119.96
1915	262	33,138	126.48
1916	67	10,307	153.84

[1] For 1910–1914 from reports of the Ontario Bureau of Mines; 1915–1916 Canadian Dept. Mines.

duced, a decrease of 73 per cent.; the average value per ton advanced to $153.84, or 21.6 per cent., and the total value, $10,307, represented a decline of 68.9 per cent.

Concentration Test.[1]—A shipment of 6059 lb. was crushed by jaw crusher and rolls till all passed 1⁄16-in. screen and was classified by a Keedy sizer into 14 sizes, ranging from 6-mesh to fines passing through the 86-mesh. The coarser sizes (6- and 8-mesh) were found not to have been freed. In a preliminary test sizes 12- to 28-mesh were treated on the James jig, two in series, but the results were not encouraging. Sizes 34 to 74 were treated on an Overstrom table with good results. Concentrates from the table were passed twice through an Ullrich magnetic separator, the second time with the poles set as close as possible and the maximum of 10 amp. used, with the results shown in the following table.

PRELIMINARY TEST

Size.	Feed, Pounds.	Concentrates, Per Cent.		
		Table.	Magnetic 1.	Magnetic 2.
34	449	4.45	2.77	2.63
42	418	2.99	1.85	1.57
50	293	2.47	2.01	1.83
62	332	2.79	2.22	2.11
74	239	2.72	2.41	2.09
Average (per cent.)...............	....	3.21	2.26	2.06

Middlings, 5.63 per cent.

In the final test all sizes that had not been treated on the table were re-crushed to pass the 24-mesh screen, classified with the Keedy sizer, and treated with the Overstrom table and Ullrich magnetic separator, in the same manner as before, with the following results.

FINAL TEST

Size.	Aperture (Inch).	Feed, Pounds.	Middling, Per Cent.	Concentrates, Per Cent.		
				Table.	Magnetic 1.	Magnetic 2.
28	0.0282	749	10.90	4.41	3.59	3.29
34	0.0229	324	7.10	4.01	3.41	3.21
42	0.0183	275	9.09	4.27	3.80	3.64
50	0.0145	352	5.12	3.70	3.20	3.12
62	0.0116	390	2.44	4.03	3.36	3.32
74	0.0089	274	3.01	3.92	3.40	3.33
86	0.0068	278	1.17	4.32	3.89	3.82
109	0.0054	324	5.94	4.25	3.88	3.82
125	0.0041	173	5.92	4.48	3.98	3.90
150	0.0036	202	4.70	4.33	4.05	3.90
200	0.0026	110	3.86	3.41	3.18	2.95
200(*a*)	....	472	2.70	2.07	1.46	1.28
Average (per cent.)	....	....	5.72	3.90	3.31	3.19

(*a*) Deister slimer.

[1] Summary Rept. Mines Branch, Canadian Dept. Mines for 1915, pp. 90–99 (Abstract).

The table concentrate gave a clean tailing of pyrrhotite and hornblende the first pass through the magnetic separator, but there still remained a little hornblende and approximately 2.25 per cent. of iron pyrites. The second time, with the poles near together and 10 amp., the tailing consisted of mica, or corundum containing iron or attached hornblende.

A chemical test seemed to show that the corundum had undergone slight alteration. A small sample of clean concentrate, from which all doubtful-looking particles were removed under the microscope, was heated to boiling with hydrochloric acid. On decanting, diluting, and adding ammonia, an aluminium precipitate showed immediately. (A small amount of attached nephelite, which might be easily overlooked under the microscope, would suffice to account for the precipitate.—L.)

Other Abrasives

Besides the abrasives used chiefly in metal working, as described in the preceding pages, several mineral and stone products are used in other industries for their abrasive qualities. Thus common sandpaper is made chiefly of quartz or garnet sand, and these minerals are applied in a variety of ways on discs, drums, and belts in finishing machines for wood and leather working. Quartz sand is used extensively in plate-glass mills, in the sand blast, with its wide range of applications, etc.

Dark massive diamonds, bort and carbonado, are increasingly important for diamond drilling in prospecting and underground exploration. The supply is so limited and the demand so great that these stones command a much higher price on the market than the average for uncut diamonds of gem quality. Diamond dust is also used by lapidaries for cutting diamonds and other hard gems. These materials to the value of $85,236 were imported in 1915.

Quarried stone in the forms of chasers, dragstones, and pavers are used in arrastras and related forms of ore and mineral grinding devices. Millstones, although little used now for grinding grain, are used in pulverizing feldspar, flint, quartz, and pigments. The production of these materials in 1915 amounted to $53,480 and imports to $17,027. Grindstones and pulpstones were also produced to the value of $648,479, with imports of $68,892; and whetstones and scythestones $115,175 and $14,247, for production and imports, respectively.[1]

Flint pebbles imported from Denmark, France, and England are used in various kinds of mills for grinding cement materials and clinker, ores, minerals, etc., and are also themselves ground for use in pottery. Im-

[1] *Min. Res. of U. S.*, U. S. Geol. Surv.

ports in 1915 amounted to $273,769.[1] Steel balls, some Canadian pebbles, and some native pebbles are also used like flint pebbles in ball mills.

The earthy abrasives, rottenstone, tripoli, diatomaceous (infusorial) earth, and "pumice" (which means volcanic ash in the United States), are used for a variety of scouring and polishing purposes. Considerable quantities of some of them are also used for filtering, heat insulation, filler for rubber, and constituents of various manufactures. The production of diatomaceous earth and tripoli in 1915 was 35,304 tons, worth $611,021; of pumice, 27,708 tons, worth $63,185. The value of imports of these is given on another page. The imported pumice is the true stony variety, chiefly from the Lipari Islands.

Artificial Abrasives

Some of these have been referred to frequently in the preceding pages. The most important in metal working are (1) silicon carbide (SiC) (carborundum, crystolon, exolon, etc.), made in the electric resistance furnace from a charge of coke, sand, sawdust, and a little salt; (2) alumina (Al_2O_3) (alundum, aloxite, adamite, boro carbone, etc.), made chiefly from bauxite, some from emery, in the electric arc furnace. The rapidly increasing importance of these products in recent years is shown by statistics published in former volumes of Mineral Industry.

Crushed steel and chilled steel shot are also much used in stone working, and steel balls are used as a substitute for flint pebbles in ball mills for grinding ore, etc. The total value of artificial abrasives sold in the United States in the past 10 years is given as follows by the United States Geological Survey.

ARTIFICIAL ABRASIVES SOLD IN THE UNITED STATES, 1906–1915

Year.	Quantity (Pounds).	Value.	Year.	Quantity (Pounds).	Value.
1906	11,774,300	$777,081	1911	21,292,000	$1,493,040
1907	14,632,000	1,027,246	1912	29,002,000	1,747,120
1908	8,698,000	626 340	1913	3,489,000	2,017,458
1909	20,468,000	1,365,820	1914	27,191,611	1,685,410
1910	23,027,000	1,604,030	1915	37,684,000	2,248,778

Selecting Abrasives for Specific Uses

Under this title R. G. Williams[2] gives a popular account of the various natural and artificial abrasives in common use, their peculiar properties, and their adaptability to certain uses or certain classes of industrial applications. Emphasis is placed on the abrasives used in metal working, particularly the artificial aluminous and silicon carbide abrasives.

[1] *Min. Res. of U. S.*, U. S. Geol. Surv.
[1] *Industrial Management*, Jan., 1917, pp. 461–468.

It is pointed out that the low efficiency of emery, on account of the high proportion of impurities (chiefly magnetic oxide of iron) is partly offset by its excellent bonding power in the vitrified wheel. The greater purity and better cutting power of corundum is offset by the limited supply available, the difficulty of cleaning and concentration, and hence the great variability of the product. These drawbacks are overcome in various degrees by the artificial abrasives.

For materials of lower tensile strength than malleable iron, such as brass, bronze, granite, marble, leather, and wood, carbide of silicon is the most satisfactory abrasive; while for steels in general, and high-speed steels in particular, an aluminous abrasive, in spite of its inferior hardness, is best, on account of its greater toughness. Also for polishing purposes, where the powder is held on wheels of leather, canvas, etc., by means of glue, the aluminous material is held more firmly and hence is more satisfactory. On the other hand, the presence of small amounts of impurities, together with differences in furnace treatment in their manufacture, produces varieties of the artificial abrasives that vary enough in their physical properties to affect their commercial uses.

Garnet

By D. H. Newland

The production of abrasive garnet last year was stimulated by the widespread industrial activity at home and by the curtailment of imports of foreign abrasives. The Adirondack mines, which yield the larger part of the domestic supply, reported a gain of about 50 per cent. in the year's shipments, a very encouraging growth in view of the general dulness which has obtained in the industry of late years. The output has averaged around 4000 tons, and only a few times has it exceeded 5000 tons, the output for 1916, however, reaching the highest total on record. Owing to the high ocean freights and other obstacles to importation Spanish garnet which had been coming into the market in increasing quantity was not so much of a factor in the trade last year. This garnet is rather a substitute for than a real competitor of the American article. It comes only in fine sizes, and is said to be obtained from alluvial deposits; such material can hardly be so fresh and hard as the garnet secured from its natural rock matrix, which is the sole source of the mineral in this country.

The largest operations in the Adirondack region were carried on by the North River Garnet Co., at Thirteenth Lake, near North River, Warren County. This company has large open quarries in a great body of garnetiferous gneiss of syenitic composition—made up of acid feldspar and hornblende, with garnet an inch or so in diameter distributed rather regularly through the mass. It is a very tough rock to break in the quarry and hard to crush. The recovery of the garnet is accomplished mostly by jigs which are of special design. The separation of the hornblende and garnet requires rather close work, inasmuch as the difference of gravity is only half a unit. The product that is obtained is a dark red garnet in sharply angular particles of superior hardness. It is shipped unsorted in bags.

The Rogers quarry on Gore Mt. in the same vicinity was operated by H. H. Barton & Son Co., and the Wevertown quarry by the Warren County Garnet Mills. The Rogers quarry is the oldest of the Adirondack workings, having been in operation since 1882, and is by far the richest of all. It is based on a long narrow band of hornblende gneiss or amphibolite, which may be either an altered dike of gabbro or an inclusion of Grenville gneiss in the country syenite. The garnet occurs in roundish masses which show strain effects and crushing and which attain very large sizes, occasionally a foot or more in diameter. Owing to its broken condition the garnet can be readily picked out of the matrix when the masses are exposed, and work is carried on entirely by hand. The particles have smooth surfaces caused by a well-developed parting. The garnet is lighter in color than that from Thirteenth Lake, but belongs to the same almandite variety.

PRODUCTION OF ABRASIVE GARNET (a)

Year.	Quantity.	Value.	Year.	Quantity.	Value.
1904	3854	$117,581	1910	3814	$113,574
1905	5050	148,095	1911	4076	121,748
1906	4650	157,000	1912	4947	163,237
1907	7058	211,686	1913	5308	183,422
1908	1960	64,620	1914	4231	145,510
1909	2972	102,315	1915	4301	139,584

(a) U. S. Geol. Surv.

ALUMINIUM

By J. W. Richards

It has become increasingly difficult to get statistics of any reliability concerning the course of the aluminium industry. Even the promoters of the industry in America profess ignorance regarding the development of the industry in Europe.

It can be assumed with considerable confidence, however, that the industry has prospered greatly and increased in output except in Switzerland and Austria. In these countries, the producing company is controlled by German capital and a larger part of the product was shipped to Germany, while the alumina consumed was obtained mostly from the bauxite deposits of the South of France. This source of supply of alumina has naturally been cut off by France, leaving the Central Empires dependent upon their own sources of alumina. To what degree the older bauxite deposits of Austria-Hungary (Wochein) have responded to the demand on them we do not know, nor to what extent the newer deposits in Dalmatia have been exploited. Reports are made of new deposits being found in Hungary, near Klausenberg, and exploited by German capital.

The industry in the United States has developed handsomely. The Aluminum Co. of America spent $20,000,000 on extensions in 1915 and 1916, with the effect of doubling its capacity in those 2 years. The Canadian output has been commandeered by the Government, but it is assumed to have been the same as in 1915. The output of Switzerland and Austria has probably been below normal. The production in France is estimated as normal, that of Italy constant, that of Great Britain diminished, and that of Norway greatly increased. A few details concerning production in these countries will be given later.

The world's production by countries, in 1916, may be estimated as follows:

	Pounds.	Metric Tons
United States	139,000,000	63,000
Canada	19,000,000	8,500
France	44,000,000	20,000
Switzerland	33,000,000	15,000
Austria	11,000,000	5,000
Italy	2,200,000	1,000
Great Britain	8,800,000	4,000
Norway	35,000,000	16,000
	292,000,000	132,500

Distributing these by firms, we would have as follows:

	Metric Tons.
Aluminum Co. of America / Northern Aluminum Co. of Canada	71,500
British Aluminium Co. (Great Britain and Norway)	7,000
L'Aluminium Française (France and Norway)	30,000
Aluminium Industrie Aktien Gesellschaft (Switzerland and Austria)	20,000
Hoyang Falden Norsk Aluminium (Norway)	3,000
Societá dell'alluminio (Italy)	1,000
	132,500

The outstanding features of 1916 have been the great increases in the United States and in Norway. It is almost certain that the production in the United States will soon reach 200,000,000 lb., and the production in Norway is increasing faster than in any other European country.

United States.—The market prices in New York during 1916 were as follows, in cents per pound:[1]

January	55.00	July	60.20
February	58.00	August	60.00
March	60.25	September	61.88
April	59.50	October	65.05
May	59.00	November	65.12
June	61.50	December	63.00
		Average	60.71

It is important to note that while market quotations were 55 to 65 cts. per lb. during the year, the Aluminum Co. of America supplied the bulk of the domestic consumption at 27 to 33 cts. per lb. This was in consonance with its policy not to impose hardships upon the manufacturers using the metal in this country, but to supply them at the same rates as prevailed in 1915, unaffected by the European demand, which put up the price of any odd lots appearing on the market as high as 65 cts. per lb., for export, and thus fixed the nominal market price. It is true that sporadic purchasers were compelled to pay these high prices, but nearly all the domestic consumption was supplied at an average of 30 cts. per lb. The Aluminum Co. of America deserves great commendation for the combination of good business sense and intelligent patriotism shown in thus sparing the consumers of aluminium in this country from the great hardships which a narrower business policy might have imposed upon them.

The Aluminum Co. of America announces that it sold 86,589,774 lb. of aluminium in 1916, in addition to supplying to its subsidiary, the United States Aluminum Co., 24,821,061 lb. for fabrication by this company. For 1918 delivery the Aluminum Co. of America has named 37 cts. per lb. as its price, although it has sold as high as 60 cts. per lb. As to costs of production, the company maintains strict secrecy, but at the rate of 6 tons of bauxite to 1 ton of metal, and at $3.50 per ton

[1] *Eng. Min. Jour.*

of bauxite on the car at the mine, the cost of the metal in the ore is only a shade over 1 ct. per lb.

PRODUCTION, IMPORTS AND VISIBLE SUPPLY OF ALUMINIUM IN THE UNITED STATES

	Production.			Imports.			Exports.	Visible Supply. (b)
				Crude.		Mfrs.		
	Pounds.	Value.	Per Pound.	Pounds.	Value.	Value.	Value.	Pounds.
1901..	7,150,000	$2,238,000	$0.31	564,803	$104,168	$5,580	$183,579	7,715,000
1902..	7,300,000	2,284,590	0.31	745,217	215,032	3,819	116,052	8,045,000
1903..	7,500,000	2,325,000	0.31	498,655	139,298	4,273	157,187	8,000,000
1904..	7,700,000	2,233,000	0.29	515,416	128,350	478	166,876	8,216,000
1905..	11,350,000	3,632,000	0.32	530,429	106,108	33	290,777	11,880,000
1906..	14,350,000	5,166,000	0.36	770,713	154,292	1,866	364,251	15,121,000
1907..	26,000,000	10,920,000	0.42	872,474	181,351	1,124	304,938	26,872,000
1908..	13,000,000	4,095,000	0.315	465,317	80,268	2,334	330,092	13,465,000
1909..	15,000,000	3,345,000	0.223	5,109,843	745,963	12,878	567,375	20,110,000
1910..	12,000,000	2,736,000	0.228	12,271,277	1,844,830	....	949,215	24,271,000
1911..	(e)28,600,000	5,720,000	0.20	(d)4,173,308	598,272	(d)63,899	1,158,603	32,773,000
1912..	(e)40,000,000	9,200,000	0.23	22,759,937	3,092,889	428,182	1,347,621	62,760,000
1913..	(e)64,900,000	13,600,000	0.21	23,185,755	3,905,977	1,090,229	966,094	88,086,000
1914..	(e)90,000,000	16,740,000	0.186	16,241,340	2,729,383	1,308,036	1,546,510	106,241,000
1915..	(e)99,000,000	31,581,000	0.319	8,534,834	1,511,988	301,863	3,682,117	107,535,000
1916..	e)139,000,000	47,260,000	0.34	6,646,385	1,729,298	55,864	15,419,134	145,646,000

(a) Not reported. (b) Production plus imports. (d) From July 1 only. (e) Estimated.

Productive capacity was increased in the United States as follows:

At Massena, N. Y., additional water power has been brought from the Cedar Rapids Power and Manufacturing Co. in Canada. At Maryville, Tenn., about 10,000 additional hp. has been purchased from the Tennessee Power Co. and brought to the plant. Ten thousand additional horsepower was also purchased and transmitted to operation at Badin, N. C. At Badin (named after the recently deceased A. Badin, president of L'Aluminium Française) the upper falls of the Yadkin River, at the narrows, is utilized by a dam 200 ft. high and 1300 ft. on the crest, which stores 210 million tons of water and furnishes 50,000 kw. The lower falls, with a height of 50 ft., will give 15,000 kw. The power station has three turbo-generators of 23,000 kw. capacity each, giving a total capacity for the whole installation of 65,000 kw. of useful current. The output of this plant should approximate 20,000 to 25,000 tons of aluminium per year, when in full action.

A large power plant was started in 1916 on the Little Tennessee River, which will be completed during 1917. The power will be carried by transmission line to Maryville, Tenn., where an additional reduction plant is being built to receive it.

A large rolling mill and stamping works has been erected by the same company on the Hudson River, at Edgewater, N. J. It contains the most modern and finest equipment in the world for rolling and working aluminium, and will supply the Eastern and Middle States with its products, thus obviating shipment from more western points.

A French journal (*Le Four Electrique*) estimates that a total of 330,000 kw. or 450,000 hp. will soon be in operation in America, carrying its yearly production of aluminium to 100,000 metric tons.

Reports have appeared in the newspapers that the Mineral Products Corporation will utilize alumina from the Utah alunite deposits (at Maryvale, Utah) to produce metallic aluminium; also other reports that this material would be shipped to a reduction plant on the Pacific Coast, and there reduced to metal. Neither proposition has materialized, the fundamental reason being that the alumina extracted from alunite has been found too impure for direct reduction, and purification by chemical means would entail a large chemical plant and cost as much as refining ordinary bauxite. Further statements in the newspapers that the Utah alumina had been used to produce new refractory products capable of withstanding 2500° C. are based on the fact that some alumina bricks were made of this residue, but their refractory nature has been grossly exaggerated; they are no more refractory than bauxite bricks.

The Aluminum Ore Co., a subsidiary of the Aluminum Co. of America, has bought 200 acres of ground at Soller's Point, Md. (near Sparrow's Point), where alumina will be made from imported bauxite. The plant will cost $1,000,000, and can be extended as needed. It will be in operation in 1918.[1]

IMPORTS OF ALUMINIUM 1913–1916
(By fiscal years ending June 30)

	1913, Pounds.	1914, Pounds.	1915, Pounds.	1916, Pounds.
Austria-Hungary	1,041,030	1,300,717	264,552	*Nil.*
Belgium	834,928	227,563	194,708	*Nil.*
France	2,580,447	2,081,468	1,798,127	*Nil.*
Germany	8,314,908	1,632,226	11,133	*Nil.*
Italy	720,992	8,816	*Nil.*	*Nil.*
Netherlands	482,122	*Nil.*	*Nil.*	*Nil.*
Norway	380,800	1,173,800	2,046,168	*Nil.*
Portugal	*Nil.*	*Nil.*	4,321	*Nil.*
Switzerland	1,058,208	2,612,747	264,552	*Nil.*
United Kingdom	4,822,180	2,110,257	1,675,616	21,876
Canada	6,722,401	4,816,067	7,499,313	8,148,309
Other countries	338	381	6,682	30,343
Total	26,958,354	15,964,042	13,765,172	8,200,528

Great Britain.—The British Aluminium Co. made profits of £379,519 in 1916 ($1,840,677), from which a 10 per cent. dividend on its stock was paid. They report a greatly increased business in light aluminium alloys, which have been greatly improved during the course of the war, and expect that the consumption after the war will absorb all the increased

[1] *Min. Sci. Press.*

production now being planned and put into operation. Its water-power construction at Kinlochleven is being rapidly completed, from which is expected part of the power in the middle of 1917, and all its capacity by the end of 1917. Extensions are being made in the firm's plant at Vigeland, Norway, which will become available in 1917. A new alumina works at Burntisland, Scotland, is near completion. The cost of production was increased in 1916 by increased wages, freight, and cost of raw material. Carbon for electrodes was also difficult to procure in sufficient quantity. Female labor is being largely used in the rolling mills at Warrington and Milton. Large stocks of bauxite are being carried, because the bulk of it comes from the South of France, and interruptions in its shipment have to be provided against.

The British Government has adopted drastic regulations concerning aluminium scrap and swarf (fine scrap) produced in Great Britain (Feb. 28, 1917). The Director of Materials has appointed refiners in certain districts, to whom all waste aluminium not treated and consumed by the maker must be sold, at scheduled prices, and re-sold after treatment at fixed prices. Directions are given to keep scrap and turnings free from admixture with brass, bronze, iron, shop-sweepings, and particularly from lead and heavy white metal. Iron should be removed by magnetic machines. Cutting compounds used in machining should not deleteriously affect the scrap, which must be dried as quickly as possible, to avoid oxidation and corrosion. Penalties are arranged for material containing over 8 per cent. of dirt, oil and moisture. By these regulations it is expected to save a large amount of aluminium and its alloys which would otherwise be lost or wasted.

All persons in Great Britain are further required to report in the first week of each month the amount of aluminium held by them on the last day of the preceding month, also all contracts for future sale or purchase of aluminium. This applies to aluminium and its alloys, also scrap, powder, etc., whenever the amount to be reported exceeds 56 lb.

Norway.—An outstanding feature of 1916 was the great activity in aluminium works in Norway. The British Aluminium Co. has an annual capacity of 600 tons in operation at Stanjfjord and 2000 tons at Vigeland. It is increasing the latter to 4000 tons, the new capacity to be available in 1917. The Société Norvegienne des Nitrures (a branch of the Société Generale des Produits Chimique d'Alais, France) has a 20,000-hp. plant in operation at Arendal, producing annually 4000 tons of aluminium, and a 30,000-hp. plant at Tyssedal, near Odde, on the Hardangerfjord, producing 6000 tons annually. The Société Norvegienne de Hoyangfaldene (called in Norway the Norsk Aluminium Cy.) is backed by Norwegian capital, and has a water power at Hoyang on the Sognefjord. It will be producing in 1917.

A rather amusing incident complicated by war conditions was the shipment of about 250 tons of aluminium from New York on two Scandinavian steamers, consigned as "asbestos" to alleged purchasers in Malmö and Gothenburg, Sweden, by L. Vogelstein of New York. After siezure by the British, the metal was discovered, and also that it was in reality destined for Aaron Hirsch & Co. in Germany. It was confiscated as lawful prize intended for the enemy.

Germany, Austria and Switzerland.—There is no aluminium works in Germany, but it is the largest consumer of aluminium in Europe, and German capital controls the Aluminium Industrie Aktien Gesellschaft, at Neuhausen, Switzerland, which has reduction plants also at Rheinfelden near Basel, at Chippis in the Rhone Valley (Canton Valais), and at Lend-Gastein in the Austrian Tyrol. All of these plants have been drawing their alumina from the bauxite deposits of southern France, where they have large chemical refining plants at St. Louis-les-Aygalades, near Marseilles. Besides this company, the firm Giulini Brothers of Ludwigshafen, Germany, had an alumina works at Ludwigshafen and a reduction plant at Martigny in the Rhone Valley, Switzerland. Since 1914 all these works have been dependent on alumina obtained from bauxite found in Silesia (Styria), Hungary and Dalmatia. Reports have appeared that these companies are extracting alumina from kaolin or clay, but the foundation for this story is probably that the Hungarian bauxite is so high in silica and low in alumina that it is virtually as poor material as clay. It is possible, however, that some high alumina clays have been used by them, being treated by a fluorine or chlorine process about as cheaply as Hungarian bauxite.

German capital has formed the "Compagnie Miniere et Industrielle d'Aluminium" of Budapest, capital 8,000,000 crowns, to exploit the bauxite mines of Count Karl Komis, situated in Bihar and Klausenburg. The bauxite is being shipped at present to Austria and Germany, but it is proposed to erect a reduction plant near Klausenburg.

The Aluminium Industrie Aktien Gesellschaft made in 1916 a net profit of 17,054,792 francs, against 9,498,754 in 1915. The annual stock dividend was put at 20 per cent.

France.—L'Aluminium Française controls all the French works, and worked them all to full capacity in 1916. Its attempt to start a plant in the United States (at Whitney, N. C.; the Southern Aluminium Co.) collapsed soon after the beginning of the war. Two works in Norway, however, have been successfully started by it. There are ten French plants, nine in the region of the Alps (Savoy) and one in the French

Pyrenees. The Société Electro-Metallurgique Française has its bauxite mines at Brignolles, and reduction plants at La Praz and St. Michel (Savoy), Argentière (High Alps), and Froges. The Société des Produits Chimiques d'Alais has its large works at St. Jean-de-Maurienne, and smaller works at Chedde, and in the Pyrenees; it owns bauxite mines at Herault in the Bouches du Rhône. The interlocking character of these French companies is difficult to unravel; the late A. Badin consolidated them into a holding trust, L'Aluminium Française, which deals as a unit with the domestic production and in negotiations with foreign firms.

Italy.—A new plant is under construction by the Societé hydroélectria de Villeneuve at Villeneuve in the val d' Aosta. It is backed by French capital.

Japan.—A plant is being erected at Nogoya, with a capital of $500,000.

Russia.—Reports are current of the discovery of bauxite in the Caucasus, and the establishment of aluminium works there.

India.—Rumors revive the project of aluminium works being established in India, where deposits of bauxite exist at Balaghot and Jubbelpore, in the central provinces. A mining lease for 30 years, for a large area, was granted P. S. Dutt in 1915, and another to J. F. Cook & Sons for 25 years. The present indications are that alumina, at least, may be extracted from these materials, and shipped to Europe or America. It would be a pity if a reduction works large enough to supply the Indian market were not established in India, using the somewhat abundant water power of the central Ghats.

Reduction

Richard Seligman, in the *Journal of the Institute of Metals* for 1916, discusses the production of CO and CO_2 gases at the anodes in the aluminium reduction pots, and finds it to vary considerably with the temperature at which the pots are run. He and Hussey analyzed the gases with the following results:

	Bath at 945° C., Per Cent.	Bath at 1055° C., Per Cent.
Carbonic acid gas	45.6	6.0
Carbon monoxide	43.6	86.4
Oxygen	0.8	1.2
Nitrogen	10.0	6.4

Dr. Bailey, in discussing these reactions, thinks it might be possible to produce CO_2 only. If such were possible and practicable, the power required to run the bath would be considerably diminished. Burning oxygen to CO returns to the electric current about 0.6 volt, considering it as a secondary reaction, while the formation of CO_2 would return

1 volt. This is a possible maximum saving in power of 0.4 volt, or about 5 per cent. of the total power consumption. The saving in carbon anodes consumed would be, however, the greater advantage, since it would reduce the anode consumption one-third to one-half. It is probable that present reduction plants are already utilizing this principle of economy as far as it is practically possible to use it.

Uses

Pure aluminium is being used for coins in France and Germany. The Chamber of Commerce of Marseilles has had struck pieces of 5 and 10 centimes (1 and 2 cts.) to replace the heavy copper 1 and 2 sou pieces.

Time fuses for shrapnel are used in place of brass, several million having been put into shells made in the United States for the Russian Government.

Several thousand tons of aluminium wire have been used in the point of the modern long-tapered rifle bullets. The copper-nickel sheath has a small pellet of aluminium inserted in its point, the remainder being filled with lead in the usual manner. The bullet is not a "dum-dum" bullet, because the aluminium is harder than the lead which it displaces, and thus tends to prevent "mushrooming" or spreading of the nose of the bullet on impact. The device is said to give a flatter trajectory and increased accuracy of fire.

Machine guns of the air-cooled type use aluminium radiators.

The explosive "ammonal," consisting of powdered aluminium and ammonium nitrate, is being used in large quantities by all combatants in the present war.

Aerial construction has absorbed large quantities of aluminium. Each large Zeppelin contains about 9 tons of aluminium framework. The *Revue des Produits Chimiques* gives the following analyses of framework of a Zeppelin, brought down in France:

	Angle Brackets	Channel Sections	Braces
Aluminium	90.27	88.68	99.07
Zinc	7.80	9.10	0.13
Iron	0.45	0.43	0.38
Silicon	0.37	0.49	0.36
Copper	0.73	0.70	0.06
Tin	0.11	0.15	
Manganese	0.27	0.45	
Nickel	Tr.	Tr.	Tr.

The first two are alloys with zinc, copper and manganese; the third is commercial aluminium. Magnesium is notable for its absence.

"Acieral" is an alloy of 92 to 97 per cent. aluminium, used by the French Government for soldiers' helmets. Its composition is not stated; it possibly contains a small percentage of chromium, manganese and magnesium.

The alloy 82 aluminium, 12 copper, 5 cadmium, and 1 silver is said to have fine mechanical properties and to be very resistant to corrosion.[1]

Aluminium dust is being extensively used in place of zinc dust for precipitating gold and silver from cyanide solutions. P. H. Crawford records careful experiments which show satisfactory precipitation, and the marked advantage, as compared with zinc dust, of saving cyanide. The saving amounted to 2.1 lb. of cyanide per ton of ore treated, of which 1.6 lb. was saved by regeneration during precipitation.

Bauxite

By A. H. Purdue

Bauxite in the United States

General Conditions.—The following is the information on the bauxite industry for 1916, as gathered from correspondence with some of the leading companies operating in bauxite.

The industry received a stimulus, due to the stopping of importations from Europe, and the increased American demand. Probably either alone would not greatly have affected the industry, but both together required that most of our mines be worked to their full capacity. A few new mines were opened and a like number of old ones re-opened. Most of the new mines are in central Georgia. No new deposits of value were discovered during the year.

One company states that the ability of the mines to supply bauxite abundantly during previous years created what is perhaps an unfortunate confidence on the part of the consumers in their sources of supply and as a result very few carry any considerable stock on hand. This, with the drastic car shortages, the frequent embargoes, and the recurring labor troubles, probably exaggerated the scarcity of the supply. Had labor difficulties been avoidable and a sufficient supply of cars obtainable, or if the consumers had had a considerable supply on hand, it is not likely that any shortage would have been felt in 1916.

PRODUCTION OF BAUXITE IN THE UNITED STATES BY STATES
(In tons of 2240 lb.)

State.	1907. (a).	1908. (a).	1909. (a).	1910. (a).	1911. (a).	1912. (a).	1913. (a).	1914. (a)	1915. (a)	1916. (a)
Alabama. Georgia..	34,271	} 14,464	} 22,227	} 33,096	} 30,170	19,587 14,173	} 27,409	18,547	25,008	46,410
Arkansas. Tennessee	63,505	37,703	106,814	115,836	125,448	126,105	182,832	200,771	272,033	378,949
Total..	97,776	52,167	129,101	148,932	155,618	159,865	210,241	219,318	297,041	425,359

(a) Statistics of the U. S. Geol. Surv.

[1] *Brass World.*

It seems probable that had the adverse conditions above mentioned not obtained, the output of the mines of this country would have been much greater than it was. The shortage of cars caused one of the large shippers to try the experiment of shipping a part of its ores by river from the Arkansas field to East St. Louis, where hitherto the movement has been entirely by rail. The plan is still in its infancy and no definite data as to its success are available.

There were no improvements in the methods of mining except a tendency to adopt steam shovels for removing overburden; but in most instances the mines are too small to justify the use of these.

As in the past, the ore from Alabama, Georgia, and Tennessee was used mainly in the manufacture of alum, for the reason that it is low in iron. The Arkansas bauxite, high in iron, has continued to be used chiefly in the manufacture of aluminium, iron not being an injurious ingredient for that purpose. The Arkansas ore is first shipped to East St. Louis, where it is purified, and from there is sent to the reducing plants.

The Aluminum Co. of America, with reduction plants at Niagara Falls; Massena, N. Y.; Baden, N. C.; Shawinigan, Quebec; and Maryville, Tenn., secures all its supply from Arkansas. The ore is calcined at the mines, shipped to East St. Louis, where it is converted into alumina by the Bayer process, then shipped to the reduction plants named. Another plant similar to the one in East St. Louis is being constructed at Baltimore.

CONSUMPTION OF BAUXITE IN THE UNITED STATES

Year.	Production.			Imports.		Consumption.	
	Long Tons.	Value.	Per Ton.	Long Tons.	Value.	Long Tons.	Value.
1907....	(a) 97,776	$480,330	$4.91	25,066	$93,208	122,842	$513,538
1908....	(a) 52,167	263,968	5.05	21,679	87,823	73,846	351,791
1909....	(a) 129,101	679,447	5.27	18,689	83,056	147,780	163,403
1910....	(a) 149,679	778,203	5.33	15,720	65,743	164,601	782,001
1911....	(a) 155,618	750,649	4.87	43,222	164,301	198,840	914,950
1912....	(a) 160,124	900,620	5.00	26,214	95,431	186,079	864,363
1913....	(a) 210,241	997,698	4.75	21,456	85,746	231,697	1,083,444
1914....	(a) 219,318	1,069,194	4.87	24,844	96,500	244,162	1,165,694
1915....	(a) 297,041	1,514,834	5.10	3,420	17,107	300.461	1,531,941
1916....	(a) 425,359	2,297,825	5.40	30	87	425,389	2,297,909

(a) Statistics of the U. S. Geol. Surv.

Alabama.—It appears that no bauxite was shipped from Alabama in 1916, but there was a good deal of prospecting for it, and according to reports some new paying deposits have been uncovered. The deposits are similar to those in northwestern Georgia, later to be described.

Arkansas.—Bauxite was discovered in Arkansas in 1887 by Dr. J. C. Branner, then State Geologist of Arkansas. The ore is closely associated with syenites upon which it in part rests, and in part upon and in Tertiary beds. In places it is bare, in others covered by Tertiary and overwash material.

"The State has produced for several years more than 80 per cent. of the bauxite mined in this country. The reason for this is that the American Bauxite Co., the principal producer in the United States, has concentrated its work in this State. The greater part of the production comes from what is known as the Bauxite district, also known as the Bryant district, which lies about 22 miles southwest of the city of Little Rock and covers an area of about 12 square miles in Bryant Township, Saline County. Bauxite, the town from which the material is shipped, is located on the Chicago, Rock Island & Pacific Railway 5 miles east of Benton, the county seat of Saline County. The mines are located on the Bauxite & Northern Railway, a spur built from Bauxite Junction, on the St. Louis, Iron Mountain & Southern Railway system. This spur crosses the Rock Island tracks at Bauxite station.

"The second and less important district is known as the Fourche Mountain district, which is located immediately south of the city limits of Little Rock, in Pulaski County, and which embraces an area somewhat larger than the Bauxite district. The two areas are about 15 miles apart."[1]

The companies operating in Arkansas in 1916 were the American Bauxite Co., Bauxite, Saline County; the Globe Bauxite Co., Benton, Saline County; the National Bauxite Co., and the Republic Bauxite Co., with offices at Little Rock.

Mining was very active, but the output was less than it would have been without the adverse conditions stated above. Nearly all the output was shipped to East St. Louis to be purified and then to the reduction plants, but a small amount was used for alum and in making abrasives.

No new deposits of importance were opened during the year, but the Republic Bauxite Co. is preparing to open a mine near Sweet Home, 5 miles south of Little Rock, in Pulaski County.

Georgia.—There are two general areas of known bauxite in Georgia. One of them is in the northwestern part of the State, and includes the counties of Polk, Floyd, and Bartow. The other is in the central part of the State, and takes a northeast course from Randolph County at the southwestern end to Wilkinson County on the northeast. Besides the bauxite in these two areas, it has been found in the southern parts of Upsom and Meriwether counties. It was in the northwestern area that bauxite was first discovered in the United States, in the year 1887.[2] The

[1] MINERAL INDUSTRY, **23**, 24 (1914).
[2] Geol. Surv. of Georgia, *Bull.* 23, p. 44 (1910).

first discovery in the central part of the State was in Wilkinson County, in 1907.[1]

The deposits in the northwestern part of the State are in the Knox dolomite, which is of Cambro-Ordovician age, and from 3000 to 4000 ft. thick. Bauxite occurs in all parts of the formation, largely along faults. The mines occur in Floyd and Bartow Counties, and while scattered, have a general direction of northeast and southwest. The mines of Alabama are in the southwestern extremity of this field. It is reported that in some localities the deposits occur in regularly stratified beds, but more commonly they form well-defined pocket deposits entirely distinct from the enclosing residual material. Kaolin and iron ore are commonly associated with the bauxite.

The deposits of central Georgia lie in beds at the top of the Upper Cretaceous, near the contact of the Cretaceous and Tertiary. They are reported to be always associated with white clay beds and are thought to have originated from these.[2] The ore varies in color from almost white and cream to bright red. It is generally pisolitic, but in places is amorphous.

The bauxite industry was active in Georgia in 1916, the output of the larger companies being supplemented by many small operators and shippers. The Republic Bauxite Co. was by far the largest shipper and operated in both sections of the State. The National Bauxite Co. operated at Toomsboro. The following mines were producers during the year: Booger Hollow mine, 5 miles from Cunningham Station, Floyd County; Merrimac mine, 3½ miles east of Halls Station, Bartow County; McIntyre mine near McIntyre, Carswell mine near Toomsboro, and Cason mine at Toomsboro, Wilkinson County; Sweetwater and Easterlin mines near Andersonville, Sumter County; and Warm Spring mine, near Warm Springs, Meriwether County.

Tennessee.—In 1906, the American Bauxite Co. opened a mine in the Knox dolomite at the east base of Missionary Ridge, on the outskirts of Chattanooga; and in 1912 the same company opened a mine near Keenburg, Carter County, in the northeastern part of the State. This mine is in the Watauga shale, which is of Cambrian age, and is older than the Knox dolomite. These two mines are on opposite sides of the State, in the Valley of East Tennessee. There are good reasons for believing that other deposits exist in the area between those named, but no new ones have been discovered.

The mines at Chattanooga were not very active during 1916, but at present the Kalbfleisch Chemical Co. is erecting a plant at Chattanooga

[1] *Loc. cit.*
[2] Geol. Surv. of Georgia, *Bull.* 18, p. 436 (1909).

which, according to reports, will be supplied by ore from the Missionary Ridge mines. The mine at Keenburg was active, but the output was limited by the scarcity of cars.

WORLD'S PRODUCTION OF BAUXITE, 1912–1916, IN LONG TONS

Country	1912.	1913.	1914	1915.	1916.
United States...	159,865	210,241	219,318	297,041	425,359
France..........	254,760	304,314	(a)	(a)	(a)
United Kingdom	5,790	8,282	8,286	11,723	10,329
Italy	6,596	6,841	3,844	5,807	(a)
India	950	1,184	514	876	(a)
Total	427,961	530,862	....	....	....

(a) Statistics not available.

Bauxite in Foreign Countries

British and Dutch Guiana.—According to press reports, the bauxite deposits of British and Dutch Guiana are near the coast, the extreme known localities being on the Waini River 28 miles from the coast in the northwestern corner of British Guiana, and on Surinam River in the eastern part of Dutch Guiana. It is thought that the deposits probably extend eastward into French Guiana. Other known deposits in British Guiana are near the mouth of the Arawari, a branch of Essequibo River, and on or near Demerara River from 65 to 80 miles above Georgetown. In Dutch Guiana, deposits have been opened on Para Creek, Rena Reu Creek and Marechals Branch, all of Surinam River, and on Cottica River. The area covered by these deposits is 62 miles long and 6.2 miles wide.

It is reported that active operations have commenced in Dutch Guiana, but on account of the fact that the leases for the Crown lands required in British Guiana have not yet been approved by the British Government, to which they were referred, no active development has been undertaken in this colony.[1]

Uses of Bauxite[2]

The chief uses of bauxite are as follows: (1) As raw material in the production of metallic aluminium; (2) in the manufacture of aluminium salts; (3) in the manufacture of bauxite bricks; (4) in the manufacture of alundum (fused alumina) for use as an abrasive. The use of bauxite in the manufacture of calcium aluminate to give a quick set to plaster compositions should be added, as well as the extended use which alundum is finding in the refractory industries.

1. The use of bauxite in the production of metallic aluminium is by far the most important of those enumerated. A large part of the out-

[1] *Eng. Min. Jour.*, Aug. 12, 1916.
[2] W. C. Phalen. U. S. Geol. Surv., *Min. Res.* of *U. S.* for 1915, Part I, p. 163.

put of Arkansas is so used, and the figures of production from this State have shown remarkable growth during recent years. A large part of the imported French bauxite has also been used in the manufacture of metallic aluminium.

2. Only the purer bauxite is used in the manufacture of chemicals, such as alum, aluminium sulphate, and aluminium salts in general. For this use freedom from oxide of iron is essential.

3. Bauxite is used in the manufacture of bauxite bricks for furnace linings. The purer the bauxite used, the more refractory is the resulting brick; moreover, the addition of bauxite to refractory clays not only increases their content of alumina but also their refractoriness. The method of making bauxite brick, a representative analysis of them, and the troubles sometimes encountered in their use were set forth in *Mineral Resources* for 1913.

Kenneth Seaver[1] has discussed the use of alumina in making bauxite brick. The two kinds of brick in common use, made of hydrous oxide of aluminium, contain 56 and 77 per cent. alumina, percentages which represent the extreme proportions of alumina of value in this industry. The characteristics of these two kinds of brick are quite different. The brick containing 56 per cent. alumina is used as a fire-clay brick, but it will withstand higher heat. The brick containing 77 per cent. alumina has been used as a substitute for magnesia brick, commonly called magnesite brick, for open-hearth and similar work. It has given excellent results. Under normal conditions it probably can not be produced as cheaply as magnesite brick.

An instance is cited where bauxite brick were used in the port end of the furnace, forming a bulkhead for that particular open-hearth furnace for 365 heats, at the end of which time a new roof was installed. The opposite port, in which magnesia brick were used, was found in worse condition. There seem to be great possibilities connected with the use of alumina brick.

4. Bauxite is used on a large scale at Niagara Falls in the manufacture of the artificial abrasive alundum. This abrasive is made in the electric furnace by fusing calcined bauxite. It is high in crystalline aluminium oxide and virtually amounts to a form of artificial corundum. The quality of the product is under complete control and can be duplicated with ease for use in the various abrasive processes, a factor of great importance in any successful abrasive industry. Alundum is particularly efficient in the grinding of steel.

5. The application of bauxite in the manufacture of calcium aluminate to give a quick set to plasters is discussed in *Mineral Resources* for 1911.

[1] *Bull. Amer. Inst. Min. Eng.*, Dec., 1915, pp. 2505–2506.

ANTIMONY

By K. C. Li

Antimony is found in many different parts of the world. It occurs in several forms, chief of which for commercial purposes are:

1. Stibnite, Sb_2S_3, gray antimony ore, or antimony glance;
2. Valentinite, Sb_2O_3, or antimony oxide;
3. Cervantite, SbO_4, or antimony ochre.

The mineral occurs in veins, pockets and sometimes in bedded deposits.

The ores are mined, dressed and smelted to produce the various forms which appear on the market as commercial products.

"Needle" antimony, also called "crude" antimony, is the sulphide of antimony which has been put through a process of liquation to separate the mineral from the gangue or waste material. Antimony metal, commonly called "regulus," is the chief commercial product and is obtained by smelting and refining the ores in reverberatory furnaces.

When molten antimony is allowed to solidify slowly without any disturbance and is covered by a layer of slag, a fern-like or "star" appearance is seen on the solidified surface. The beauty of this star-formation is sometimes taken to indicate the purity of the metal, but it is not always safe to judge the purity by the "star" appearance.

Pure metallic antimony is of silvery luster and does not easily rust. It is a very brittle metal, can be broken by a sharp blow, and may be readily crushed to a fine powder. It is a good conductor of heat and electricity, and its specific gravity is about 6.5. The objectionable impurities are sulphur and arsenic.

Antimony is also found and produced in the form of antimonial lead.

The following are analyses of different brands of antimony made by (A) The American Sheet and Tin Plate Co. and (D) The National Lead Co.

METALLIC ANTIMONY ANALYSIS

	Cookson's "C."		Hallett's "H."	
	A.	D.	A.	D.
Lead	0.041	0.102	0.669	0.718
Tin	0.035	Tr.	0.175	0.012
Arsenic	Tr.	0.092	Tr.	0.210
Bismuth		None	.....	None
Copper	0.040	0.046	0.038	0.046
Cadmium		None	.....	None
Iron	0.010	0.004	0.014	0.007
Zinc	Tr.	0.034	Tr.	0.023
Nickel and cobalt		0.028	.....	None
Sulphur		0.086	.....	0.128
Antimony*		99.608	.....	98.856
Total		100.000 per cent.		100.000 per cent.

	Japanese "MC." A.	Japanese "MC." D.	Chinese "OO" W. C. C. Brand. A.	Chinese "OO" W. C. C. Brand. D.
Lead	0.443	0.424	0.018	0.029
Tin	0.175	0.012	0.035	None.
Arsenic	0.008	0.095	0.017	0.090
Bismuth	.....	None	.....	None
Copper	0.034	0.043	0.008	0.012
Cadmium	.....	None	.....	None
Iron	0.015	0.007	0.007	0.004
Zinc	Tr.	0.023	Tr.	0.027
Nickel and cobalt	.....	None	.....	Tr.
Sulphur	.....	0.201	.....	0.078
Antimony*	.....	99.195	.....	99.760
Total	.....	100.000 per cent.		100.000 per cent.

* By difference.

Production of Antimony in 1916.—Prior to the commencement of the European war, antimony was a mineral of comparatively little importance. Although it could scarcely be said that the world's supply of antimony was abundant, the uses for antimony in ordinary times were so few that the supply was more than able to take care of the demand. The mineral was being mined in China, Bolivia, France, Italy, Mexico, Germany, Hungary, United States of America, Japan, Africa, Australia and Spain. With the opening of hostilities in Europe, antimony shared, to an extraordinary extent, in the new era of activity and prosperity experienced by all those metals used for the making of war munitions and supplies.

In normal times the price paid for antimony metal or regulus was around 7 to 8 cts. per lb., and the prices paid for needle antimony and antimony ore were in proportion to the above. These prices were not sufficiently high to encourage the mining of antimony, except in those countries where the price of labor was low, and where the purity of the ores allowed the production of high-grade metal at low cost. The war demand led to a sensational and very rapid advance in prices, and consequently to a greatly increased activity in mining. Countries such as the United States which had fair supplies of low-grade stibnite ores took advantage of the boom in prices to develop their antimony industry. In China, which country is generally conceded to contain the most extensive bodies of this mineral, mining and smelting of antimony were developed on an unprecedented scale. In Bolivia the mining of antimony was greatly stimulated, and large shipments of ore were made during 1915, and during the first few months of 1916.

In the United States the prices paid for antimony at the end of 1915 and the beginning of 1916 were from 40 to 45 cts. per lb., which prices were considerably higher than those obtained in any other part of the world, except in one or two countries, like Sweden, where antimony is said to have at one time reached $2 per lb.

Production in the United States

Naturally, therefore, the mining of antimony in America itself was greatly increased and during 1915 according to figures collected by the U. S. Geological Survey, 5000 tons of antimony ore containing about 2100 tons of antimony was produced. Practically all the operations were new, as the largest previous production of domestic antimony was 380 tons of ore in 1892. Among the states showing in the increased production was Alaska. According to the *Mining and Engineering World*, of Oct. 7, 1916, stibnite has been noted at 67 localities in Alaska, but only a few have produced and marketed ore. In 1915, the production of antimony ore was begun at four mines in the Fairbanks and two in the Nome district. All the operations were small and primitive. It is estimated that during 1915 ore to the value of $74,000 was mined and shipped from Alaska. The mining continued in a small way during the first half of 1916, then the fall in prices of antimony during midsummer put an end to these operations.

The largest part of the domestic output for 1915 was made from deposits near Wild Rose Spring in California. These deposits have been known for many years, but were not exploited until the high prices of 1915 encouraged their exploitation. The deposits contain considerable antimony ochre, as well as stibnite. These deposits, as well as some others in Kern County, were operated by the Western Metals Co. Other deposits were mined in California at many points in Kern County, in the east end of San Benito County, and on Moores Flat, near Grass Valley, in Nevada County; considerable quantities were mined at many points in Nevada ranging from Pass Canyon, in the Pine Forest Range, southward to the vicinity of Tonopah and eastward to Joy; Oregon, Washington, Idaho, Arkansas and Utah all produced small quantities of ore, and four smelting plants were operated on antimony ores alone. The Chapman Smelting Co. of San Francisco, after being inoperative for several years, began smelting ores which they mined in Nevada or bought from other parts. The Western Metals Co. built an antimony smelter at Los Angeles and operated mines in California and Nevada. They also bought ores from Alaska and foreign countries. Antimony was mined in Nevada and smelted at Matawan, N. J., by the Magnolia Metal Co. and the Antimony Smelting & Refining Co., of Seattle, started a smelter at Van Asselt, Wash., for the production of antimony oxides and metal. Needless to say, most of these enterprises were put out of commission by the rapid decline of antimony prices in August, 1916.

Production in Other Countries

South Africa is another part of the world in which the mining of antimony has been encouraged by the high prices ruling in 1915. There has been considerable mining along the Murchison Range, regular shipments of ore having been made for a number of months. It is said, however, that Murchison Range is not the only source of this mineral in South Africa. A company known as Antimony, Ltd., has recently opened up a fairly good ore-body, near Steynsdorp, and has made experiments in smelting with the result that a furnace of modest dimensions has been proposed. As previously mentioned, cost of labor has been one of the main factors in determining whether an antimony deposit can be profitably worked, and as South Africa enjoys the advantages of cheap labor, it may be possible for the industry to develop even under normal prices and conditions.

In northern Africa antimony deposits occur in Algeria and the working of these has been greatly developed in 1916. According to figures given by the *Metal Bulletin* of London, Algeria produced in 1916, about 28,473 metric tons of antimony ore, whereas the production in 1915 was 9022 tons and in 1914 only 1100 tons. Antimony smelters are being built at Pont de-Vivaux near Marseilles.

Next to China, Bolivia seems to have the largest supplies of antimony ore. Generally speaking antimony has occupied only a place of secondary importance among the mineral industries of Bolivia, but the high prices of 1915 encouraged mining there also. The output for 1915 was said to be about 17,900 tons and in the first 4 months of 1916, over 10,000 tons was exported, the value of the exports being estimated at over $1,500,000. Most of the Bolivian ore was shipped to England for munitions purposes. About the middle of 1916, shipments of Bolivian ore practically ceased owing to the rapid fall in prices.

There is no doubt that the antimony deposits in European countries are at present being exploited to their utmost limits, but most of the antimony is being used up in the production of munitions of war. London newspapers state that the Skoda Works are re-opening the old antimony deposits at Heinrichshain, near Prosau, Bohemia, to which latter point a wire-rope railway for the transportation of the ore is to be constructed.

Of all the countries producing antimony, China has during the past 3 years presented the most interesting spectacle. The sensational fluctuations in antimony prices have, more than anything else, brought home to the Chinese people and merchants the fact that a war is being waged in Europe. China is the world's greatest producer of antimony, but previous to the outbreak of war, antimony mining was being carried on in a very slipshod fashion. A large number of private individuals or small companies were mining the ore in a very primitive fashion, and the facilities for smelting were not very extensive; consequently the antimony industry, like many other industries in China, was being exploited by outsiders who bought up the ore in China and shipped it to other countries for smelting. The first smelters for the reduction of antimony were established about 1907, when the Tai Shing Mining Co. was organized for the production of crude or needle antimony. This company, being successful, was followed by others, until in 1912 eight smelters were at work and more than 100 mining companies were formed. About 1908, the Wah Chang Mining & Smelting Co. was formed, to control the Kuan Tong Antimony Mining Co. of Yi-Yang, the first company to discover the antimony deposits in China in 1897. The Wah Chang Co., by the introduction of scientific methods in mining, has become not only the leading concern producing antimony in China, but also a force to be reckoned with in the world's antimony trade. The high price of 1915 greatly stimulated the production of antimony. Exports increased by 5,995 tons in 1915, and the value advanced by $2,010,164. The production was further accelerated during the first few months of 1916. Although several new small producers have arisen, the chief factor in the increased production was the Wah Chang Mining & Smelting Co. Ltd. of Changsha. This company had not only increased its production, but also greatly extended its smelting plant, and large shipments of antimony metal were made to the United States of America,—about 62 per cent. of the total importation in 1916, according to the figures of the United States Bureau of Foreign and Domestic Commerce. The antimony industry in China is being better organized as time goes on and this organization is largely due to the influence of the Wah Chang Co. The antimony deposits of China occur in the Provinces of Hunan, Kwangsi, Kwangtung, Yunnan and Kweichow. The Hunan Province is by far the most important and makes about 95 per cent. of China's production. It possesses the purest ores, practically free from arsenic, and carrying 20 to 64 per cent. antimony. Changsha is the center of the mining industry in Hunan.

The accompanying map shows Hunan Province, with the antimony deposits, chiefly in three districts, Yi-Yang, Hsin-Hua, An-Hua.

With the increased facilities for smelting in Changsha and Hankow efforts are being made to concentrate the smelting of antimony ores in China itself. The metal is shipped down the river from Changsha to Hankow and thence to Shanghai for shipment abroad.

The total exports of antimony (regulus and crude) in 1916 from

China amounted to 24,727 short tons valued at $9,340,567, as compared with 23,933 short tons valued at $2,893,436 in 1915. Exports of antimony ore in 1916 were 12,968 short tons valued at $1,092,762, as compared with 1842 short tons valued at $83,025 in 1915. Nor should it

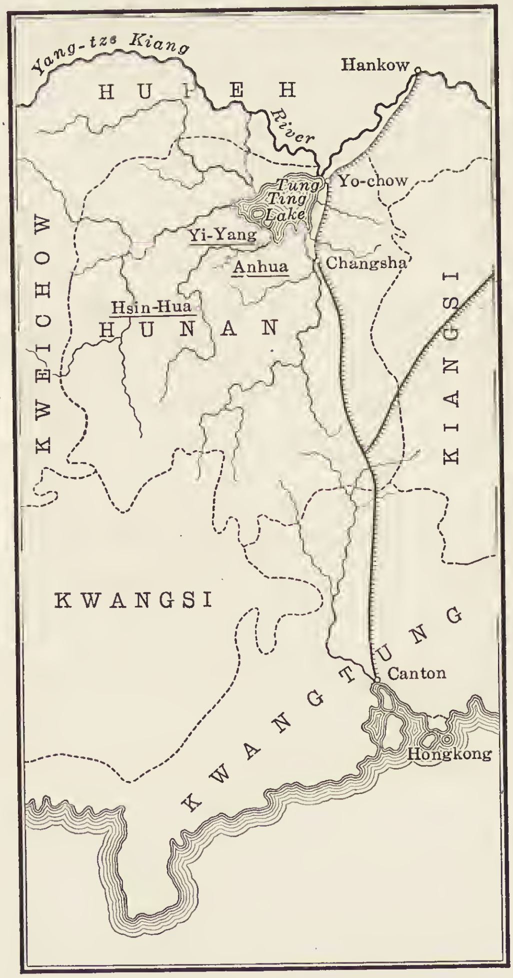

FIG. 1.—Province of Hunan, showing antimony districts.

be overlooked that a great proportion of the so-called "Japanese antimony" is produced from ores mined in China. There seems little reason to doubt that China can, with proper organization, maintain the position she has secured as the world's foremost producer of antimony.

PRODUCTION OF ANTIMONY METAL IN FOREIGN COUNTRIES
(In metric tons)

	1904.	1905.	1906.	1907.	1908.	1909.	1910.	1911.	1912.	1913.	1914.	1915
Austria	36	90	*Nil.*	207	162	*Nil.*	*Nil.*	*Nil.*	13	......	.....	....
China(*b*)	.....	3,353	3,829	2,316	9,356	7,937	6,643	6,986	13,531	13,032	19,645	23,357
France	2,116	2,396	3,433	3,945	3,850	5,444	4,640	4,775	5,406	......	......	....
Hungary(*a*)	1,007	756	1,322	841	670	695	782	892	859	1,038	.....	....
Italy	836	327	537	610	345	59	*Nil.*	*Nil.*	*Nil.*	76	138	481
Japan	321	190	627	248	198	157	120	97	80	21	3,852	8,320

(*a*) Regulus. (*b*) Exports of regulus and refined metal.

IMPORTS OF ANTIMONY
(Into the United States according to the Bureau of Foreign and Domestic Commerce)
In Pounds

Month.	1915.		1916.	
	Ore.	Metal.	Ore.	Metal.
January	231,200	2,239,553	660,309	89,600
February	....	1,040,336	448,684	2,246,623
March	76,608	986,164	803,097	1,202,150
April	297,721	769,949	982,851	2,984,600
May	229,001	1,516,127	1,933,472	2,642,560
June	117,600	1,446,979	1,755,817	4,960,751
July	118,195	2,439,601	1,505,812	380,800
August	772,691	661,030	596,979	3,414,693
September	109,015	2,320,412	47,315	342,185
October	131,906	439,413	520,051	....
November	250,066	617,598	163,726	941,548
December	1,040,009	3,006,868	67,310	544,320
Totals	3,374,012	17,484,030	9,485,423	19,749,830

The following table shows the imports of antimony metal and ore from China alone during 1916:

IN POUNDS

Month.	Antimony Ore.	Antimony Metal.
January	....	89,600
February	....	1,310,400
March	....	504,000
April	39,200	1,741,520
May	347,730	1,029,280
June	39,200	2,832,800
July	470,400	156,800
August	117,600	3,180,800
September	....	223,485
October	310,464	....
November	156,800	940,800
December	....	56,000
Total	1,481,394	12,065,485

A comparison of the above table with the preceding one shows at a glance the importance of China as an antimony producer.

YEARLY IMPORTS OF ANTIMONY METAL AND ORE FROM 1900 TO 1916 INTO THE UNITED STATES

Year.	Metal.	Crude and Ore.	Year.	Metal.	Crude and Ore.
1900	3,654,822	6,089,134	1909	9,557,956	3,453,542
1901	3,640,505	1,682,301	1910	7,955,945	1,346,962
1902	5,388,739	3,129,069	1911	8,486,137	1,641,467
1903	4,694,309	2,714,617	1912	13,936,873	1,562,066
1904	4,268,045	2,488,518	1913	12,479,727	4,021,486
1905	4,941,247	1,970,788	1914	13,110,426	2,606,349
1906	10,305,734	1,972,658	1915	17,484,030	3,374,012
1907	9,600,901	2,771,387	1916	19,749,830	9,485,423
1908	8,089,915	3,287,218			

The increased imports during the last few years have come chiefly from China and Japan. The latter country, although possessing only very small supplies of antimony ore, has been very active in purchasing ores in China and other parts and smelting them in Japan. Most of the Japanese antimony is produced in that way.

A very considerable proportion of the antimony imported by the United States during 1916 was re-exported to Canada for making munitions of war. On that account it is difficult to estimate just exactly how much of the antimony was consumed in the United States alone.

The figures given in the following table are taken from the United States Geological Survey publications.

ANTIMONY STATISTICS OF THE UNITED STATES
(In tons of 2000 lb.)

Year.	Imports, Antimony Content.				Production. (a)		
					In Hard Lead.		
	Metals or Regulus.	In Ore.	Type Metal.	From Domestic Ore.	From Domestic Ore.	From Imported Ore.	Recovered from Old Alloys, Scrap, Dross, etc.
1905..........	2,869	988	1,228	493	2,747	....	....
1906..........	3,950	1,124	1,853	404	1,362	....	....
1907..........	4,331	1,380	1,369	351	1,561	....	....
1908..........	4,057	1,640	422	....	2,246	....	....
1909..........	4,826	1,693	1,327	....	1,617	743	1,556
1910..........	4,950	*Nil.*	1,109	....	1,598	631	2,779
1911..........	5,479	*Nil.*	727	....	1,543	711	2,369
1912..........	6,969	*Nil.*	52	....	1,224	725	2,506
1913..........	7,667	25	50	....	2,204	304	2,705
1914..........	6,535	993	94	....	2,530	175	2,645
1915..........	8,742	1,682	....	....	5,364	....	3,102
1916..........	9,875	*4,742	....	....	....	....	....

(a) Figures of U. S. Geological Survey. * Ore only.

The Antimony Market

The past 3 years have shown that antimony is pre-eminently a war metal. From the beginning of 1908 to the middle of 1914, antimony prices fluctuated very slightly indeed. The month of July, 1149, found the price in New York at about 6 cts. per lb. In April, 1915, English brands of antimony were cut off from the New York market and by the month of March, 1916, the prices of metal had reached the extraordinary level of 45 cts. per lb. About this time the effects of the enormously increased production of the mineral began to be felt and the market declined rapidly until in August, 1916, the prices had almost reached their pre-war level. The results of this decline can be more easily imagined than calculated. Production of antimony in the United States was brought to a standstill; shipments of antimony ore from Bolivia and other countries fell off rapidly; and in China, where speculation had been rife and reckless, prospective fortunes vanished overnight. Naturally this also resulted in the Chinese production being greatly curtailed. Toward the end of 1916 when it seemed certain the war would continue for another year, antimony prices began to recover somewhat; and although they have not reached their former high level present prices are quite good.

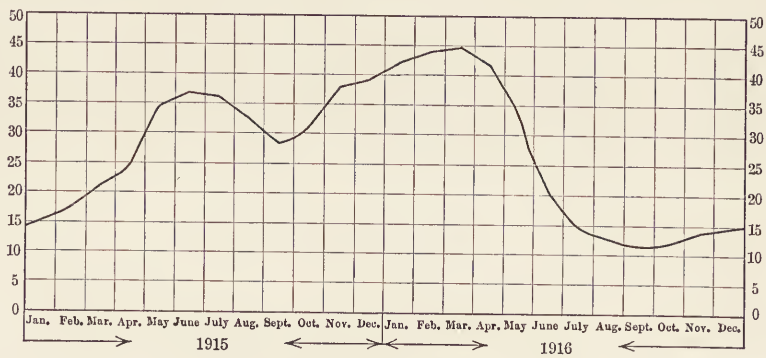

FIG. 2.—Antimony prices during 1915 and 1916.

In normal times English brands of antimony, notably Cookson's and Hallett's commanded a better price than other brands on the New York market, and the withdrawal of these English brands from the market gave the Wah Chang Mining & Smelting Co. a chance to demonstrate that at least one brand ("W.C.C.") of Chinese antimony is the equal of the best brands now manufactured. It is therefore likely that the prewar standards of value in antimony will not be revived. The following table gives an idea of the prices of antimony metal from 1910 to 1916:

In Great Britain the antimony market during the greater part of the war has been controlled by the Government and maximum prices have been fixed from time to time. This, of course, did not mean that the prices fixed officially were the prices actually ruling for antimony because as a matter of fact when the price was nominally £95 a ton not more

AVERAGE MONTHLY PRICES OF ANTIMONY IN NEW YORK FROM 1910–1916
(In cents per pound)

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
1910													
Cookson's.........	8.50	8.47	8.36	8.44	8.44	8.24	8.18	8.28	8.31	8.26	7.92	7.63	8.25
U. S..............	7.99	7.97	7.94	7.94	7.94	7.94	7.94	7.94	7.94	7.90	7.66	7.44	7.88
Others............	7.74	7.58	7.31	7.44	7.44	7.44	7.40	7.33	7.31	7.40	7.19	7.06	7.39
1911													
Cookson's.........	8.25	8.38	9.56	9.54	9.50	8.75	8.50	8.44	8.31	8.14	7.97	7.78	8.59
U. S..............	7.74	8.02	9.13	9.13	8.97	.....	.....	7.94	7.84	7.71	7.61	7.50	8.16
Others............	7.50	7.65	9.00	8.52	7.99	7.42	7.35	7.36	7.26	6.96	6.92	6.82	7.54
1912													
Cookson's.........	7.53	7.27	7.65	8.05	8.02	8.09	8.42	8.59	9.12	10.30	10.39	10.20	8.90
U. S..............	7.47	7.44	7.56	7.75	7.75	7.78	7.96	7.98	8.50	9.62	9.86	9.62	8.26
Others............	6.88	6.83	6.86	6.94	7.10	7.21	7.50	7.70	8.26	9.30	9.30	9,18	7.76
1913													
Cookson's.........	9.94	9.47	9.28	9.13	8.88	8.79	8.54	8.38	8.37	7.60	7.62	7.50	8.73
U. S..............	9.53	9.09	8.85	8.50	8.37	8.27	8.08	7.91	7.93	7.27	7.30	7.25	8.22
Ordinaries.........	8.97	8.25	8.18	7.98	7.79	7.64	7.55	7.39	7.37	6.49	6.45	13.90	7.52
1914													
Cookson's.........	7.39	7.25	7.31	7.36	7.37	7.25	7.21	17.25	11.83	14.68	17.75	16.10	10.73
U. S.	7.11	7.06	7.07	7.05	7.02	7.00	6.94	15.80	.....	.....	.....	.....	.....
Ordinaries.........	6.13	6.10	6.05	6.01	5.84	5.83	5.64	13.80	9.94	12.06	14.45	13.31	8.76
1915													
Cookson's.........	17.56	20.43	27.84	32.07	Quot	ation	s cea	sed.					
Chinese and Japanese............	15.24	17.62	20.90	23.97	34.71	36.53	35.98	32.57	28.50	30.96	37.38	39.36	29.64
1916													
Cookson's.........	None	offere	d										
Chinese and Japanese............	42.26	43.77	44.71	41.35	32.20	20.40	14.55	12.62	11.57	12.44	13.65	14.39	25.33

1910–14 from *Eng. Min. Jour.*
1915–16 from *Metal Statistics.*

than £45 to £50 could be obtained. It is idle to predict the future of the antimony market, but there are strong reasons for believing that even after the war is over antimony prices will not immediately fall to their pre-war level. The writer fully explained his reasons for this belief in an article published in the *Mining and Scientific Press* on Feb. 3, 1917.

Uses of Antimony

Owing to its very brittle character pure antimony metal can not be used alone for manufacturing purposes. It is, however, used in several important alloys, and antimony salts are also used for various purposes. The chief alloys of antimony and their uses are briefly outlined below:

1. *Britannia Metal.*—This is an alloy of tin and antimony containing up to 20 per cent. of antimony and having small percentages of copper, etc. The metal is used to make spoons, tea pots and other similar articles.

2. *Bearing or Babbitt Metal, Also Called "White Metal."*—This is an alloy generally composed of tin, antimony and copper, and is used for manufacturing or renewing machine bearings.

3. *Type Metal.*—This is composed of lead, antimony and tin; it is used for making the type for printing presses, etc. The addition of the antimony helps to perfect the moulding of the letters and renders the type hard enough to stand the pressure of printing.

4. *Shrapnel Lead.*—This is a mixture of lead and antimony (12 to 25 per cent. Sb) which is most extensively used in the production of shrapnel bullets. The addition of the antimony hardens the lead and prevents the bullets from losing their shape on the bursting of the shell. Some writers have said that the reason for using antimony in shrapnel is to make the bullets brittle so that they will break up on the exploding of the shell.

5. *Hard Lead.*—This is a mixture of lead and antimony which perhaps falls more properly under the section on lead. As used in this country, hard lead contains about 5 to 7 per cent. antimony, and it is very often produced by the smelting and refining of antimonial lead ores. It may also be obtained by smelting antimony ores and lead ores together in the necessary proportions. Hard lead is used for a great variety of purposes.

6. *Miscellaneous.*—There are several uses to which antimony is put that are not so well known as the foregoing and might be mentioned here. One of these is its mixture with lead in the manufacture of storage batteries and accumulators. Very pure antimony is required for this purpose.

The writer has recently been informed that a large Canadian concern has carried out a number of experiments with the object of determining whether antimony could be substituted for tin in the construction of electric cables. It is understood that these experiments have been successful, and if such be the case, there has opened up a new large field for antimony. In ordinary times, antimony is so much cheaper than tin that the substitution of antimony for tin in cable work should lead to a great reduction in cost of the cables.

Antimony is also used as an alloy with lead and other metals in the manufacture of toys, photo-frames and other bric-a-brac.

Uses of Antimony Compounds

There are a number of uses to which antimony compounds may be put, and these uses are briefly described in an article on antimony written by Mr. B. Dunstan, Chief Government Geologist of Queensland, Australia, and published by the *Queensland Government Mining Journal* of Feb. 15, 1917. Part of the following information was taken from Mr. Dunstan's article.

1. *Pigments.*—(*a*) "Antimony white" is the tri-oxide of antimony which is formed as a very fine powder in the flues and dust chambers of

antimony roasting furnaces. It can be collected in this form and used without further treatment for paint purposes.

(*b*) "Antimony black" is metallic antimony deposited electrically or chemically as a fine powder from an antimony solution, and is used as a bronzing pigment for metals and plaster casts.

(*c*) "Antimony vermilion," a red tri-sulphide of antimony, may be formed by precipitating an antimony salt from solution with sulphuretted hydrogen. As a pigment it is in many ways superior to red oxide of lead, red chromate of lead, or mercury vermilion.

(*d*) "Antimony yellow" is produced by the slow oxidation of the sulphide; various shades of yellow are formed by mixing it with red lead and zinc white.

(*e*) "Antimony blue," "antimony violet," etc., are other pigments produced by mixtures of the foregoing with other mineral compounds.

2. *Rubber Vulcanizing.*—Vulcanized rubber is used for several purposes, one of the chief uses being for the insulation of electric cables. The red tri-sulphide of antimony is fused with sulphur and thus converted into penta-sulphide, the product being dissolved in a solution of sodium sulphide. The penta-sulphide crystallises out as a red powder on the solution being evaporated, and in the vulcanizing process this powder parts with the excess of sulphur and is reduced again to the tri-oxide. The latter mixes mechanically with the rubber, giving a red color.

3. *Enamelling.*—In enamelling processes and in glass staining antimony tetroxide is mixed with white lead and borax to produce a yellow color. A white enamel is now made with the tri-oxide, this compound to some extent replacing tin oxide. According to Prof. H. F. Staley, these antimony enamels have been quite successful.

4. *Shrapnel.*—Reference has already been made to the use of antimony in shrapnel bullets, but antimony sulphide has been used to form part of the powder composition for shrapnel shells required to produce a dense cloud of white smoke on bursting.

5. *Matches.*—Antimony tri-sulphide is used in making safety (Swedish) and wax matches, as well as in the composition on the side of the box on which the matches are ignited. The heads of the matches contain about 3 per cent. of the tri-sulphide, while the composition on the box contains about 8 per cent. of the same material. The antimony tri-sulphide is probably obtained from antimony crude.

ARSENIC

By Allison Butts

The demand for arsenic in the United States was well sustained throughout the year, and the production was stimulated in accordance. Imports, on the other hand, were considerably less, which tended to further increase domestic production.

The increased demand came largely from the glass makers. Their tendency has been to use less antimony oxide, on account of the very high price of the latter.

The market quotations of the *Engineering and Mining Journal* show a sharp rise in the price of white arsenic at the beginning of the year from 4 and 4½ to 6 and 6½ cts. per lb. This price held with but slight variation through the year until near the close, when there began a remarkable rise which carried the price above 15 cts. in April, 1917.

Red arsenic was scarce and quoted at 65 and 70 cts. per lb. in the last quarter.

STATISTICS OF WHITE ARSENIC IN THE UNITED STATES

Year.	Production.			Imports. (*a*)			Total.	
	Pounds.	Value.	Per lb.	Pounds.	Value.	Per lb.	Pounds.	Value.
1900	....	......	.....	5,765,559	265,500	0.04¾	5,765,559	265,500
1901	600,000	$18,000	$0.03	6,989,668	316,525	0.04½	7,589,668	334,525
1902	2,706,000	81,180	0.03	6,110,898	280,055	0.04½	8,816,898	361,235
1903	1,222,000	36,691	0.03	7,146,362	256,097	0.03½	8,368,362	292,788
1904	996,456	29,504	0.03	6,391,566	226,481	0.03½	7,388,022	255,985
1905	1,545,400	50,225	0.03¼	6,444,083	219,198	0.03⅓	7,989,483	269,423
1906	1,663,000	83,150	0.05	7,639,507	336,609	0.04½	9,302,507	419,759
1907	2,020,000	101,000	0.05	9,922,870	553,440	0.05½	11,942,870	654,440
1908	2,603,505	99,193	0.03¾	9,592,881	417,137	0.04⅜	12,196,386	516,330
1909	2,015,880	57,957	0.02⅞	7,183,644	272,493	0.03¾	9,199,524	330,450
1910	2,652,000	66,300	0.02½	8,257,474	251,716	0.031	10,909,474	318,016
1911	6,162,000	123,240	0.02	5,404,263	159,626	0.030	11,566,263	282,866
1912	6,282,000	190,757	0.035	6,758,946	246,815	0.037	13,040,946	437,572
1913	4,750,000	142,340	0.03	6,688,216	285,537	0.043	11,438,216	427,877
1914	9,340,000	313,147	0.034	4,079,372	165,266	0.040	13,419,372	478,413
1915	10,996,000	302,116	0.027	3,573,624	154,517	0.043	14,569,624	456,633
1916	11,972,000	555,186	0.047	2,180,321	124,844	0.057	14,152,321	680,030

(*a*) Arsenic and sulphide.

The United States production is entirely a by-product in the smelting of lead, copper, gold and silver ores, being recovered from flue dust and fume. This recovery is bound to increase in the future both on account of the greater attention paid to by-products and on account of the wider use of fume collecting devices, made necessary to prevent smoke damage.

The amount lost annually from the smelter at Anaconda, Mont., alone is greater than the entire country's production. Smelter fumes frequently contain 20 to 25 per cent. As_2O_3.

Some progress has been made in the methods of fume treatment, which consist essentially of sublimation of the arsenic to an impure oxide (96 to 98 per cent. As_2O_3), refining, if desired, to above 99.5 per cent. by re-sublimation. A process devised by Duncan Anderson, Jr.,[1] is being applied, in which the arsenical material is first treated with sulphuric acid, and the arsenic volatilized as sulphate. A better separation is obtained and the residue containing valuable metallic sulphates is in condition for leaching.

The U. S. Smelting, Refining and Mining Co. recovers arsenic in the process of the recovery of cadmium from bag-house dust at the lead smelter, Midvale, Utah, using a process developed by R. H. Stevens.[2] The arsenic recovery is by dead-roasting, volatilizing and condensing.

An English metallurgical plant employs the principle of the vacuum cleaning pump to transport white arsenic from the settling chambers to the packing house, avoiding all loss of dust with its consequent danger to handlers.[3]

In addition to its use in the glass-making industry, arsenic finds a limited use in taxidermy and as an insecticide, especially in the manufacture of Paris green and tree sprays. Its poisonous effect on animal life does not extend to vegetation. Consequently the quantities given off in smelter smoke are not harmful, except possibly to grazing animals, which has never been proven. Small amounts taken in the system are probably eliminated without harm. The sulphides of arsenic, orpiment and realgar, are used as pigments.

WORLD'S PRODUCTION OF ARSENIC
(In metric tons)

Year.	Canada. (a)	Germany. (b)	Italy. (d)	Japan. (a)	Portugal. (d)	Spain. (b)	United Kingdom (a)	United States. (a)	France. (d)
1901	630	2,549	......	10	527	120	3,416	272	7,491
1902	726	2,828	......	12	736	71	2,165	1,226	5,372
1903	233	2,768	50	6	698	1,088	916	554	6,658
1904	66	2,829	80	4	1,370	400	992	452	3,117
1905	*Nil.*	2,535	......	8	1,562	1,140	1,552	701	3,627
1906	*Nil.*	3,052	......	5	1,322	1,114	1,625	754	6,534
1907	317	2,904	73	7	1,538	2,400	1,523	916	7,900
1908	649	2,822	451	20	1,655	2,004	2,007	1,301	2,381
1909	1,020	2,911	*Nil.*	8	1,420	506	2,911	914	2,141
1910	1,363	3,066	*Nil.*	12	974	444	2,187	1,203	8,045
1911	1,815	2,981	16	6	887	331	2,178	2,800	19,000
1912	1,858	4,869	*Nil.*	......	1,006	(c)	2,228	2,855	81,880
1913	1,538	5,008	*Nil.*	......	925	....	1,716	2,158	70,613
1914	1,576	....	*Nil.*	......	960	....	2,007	4,238	....
1915	2,174	....	*Nil.*	15	....	....	2,536	4,990	....
1916	1,983	....	......	(c)	....	....	2,575	5,430	....

(a) White arsenic. (b) Oxide, sulphide, etc. (c) Not yet available. (d) Ore.

[1] U. S. Patent 1,198,095, Sept. 12, 1916; *Eng. Min. Jour.*, **102**, 943.
[2] *Min. Eng. World*, **45**, 661.
[3] *Min. Mag.*, July, 1916.

ASBESTOS

By Oliver B. Hopkins

The asbestos market has been exceptionally active during the past year, owing to the demand for asbestos in making war supplies and to the high price which the high-grade fiber has brought. No. 1 crude, which in normal times sells for $300 to $400 per ton, is reported to have sold as high as $1000 to $1200 per ton. Although the world's production in 1916 was probably not much, if any, in excess of what it was in 1915, there was a marked decrease in the stock on hand. There was an improvement in the method of handling the asbestos obtained from the Canadian mines, which supply the bulk of the world's production, by the installation of steam shovels and inclines in the place of cable-derrick equipment.

There was a decrease in the production of asbestos in the United States in 1916 as compared with 1915, although an exceptional amount of interest is being taken in the new and unworked deposits. If the present high prices prevail during the coming year, it is likely that the production of this country will be materially increased. There was a moderate increase in the total asbestos production of Canada, amounting to 11 per cent. A notable feature of the industry is the increased production of crocidolite, blue asbestos, in South Africa, coming principally from Cape Province. The supply of this type is described as being inexhaustible and in all its physical properties except its power to withstand high temperatures it is said to be equal if not superior to the Canadian asbestos, chrysotile.

There are three main types of asbestos on the market: chrysotile or serpentine asbestos, amphibole asbestos, mainly anthophyllite, and crocidolite, blue asbestos. Chrysotile is the principal type of asbestos of commerce; it is mined in Canada, Arizona, Russia, and Rhodesia. It occurs as veins in serpentine rock and forms from 6 to 7 per cent. of the total rock mass in the workable mines. Amphibole asbestos is worked in Georgia and Idaho. At both of these localities it makes up the mass of the rock, which is composed of bundles of rather short brittle fibers. It is suitable for only the lower-grade uses. Crocidolite is a finely fibrous, asbestiform mineral with great tensile strength and can be substituted for chrysotile for many purposes. Owing to the fact that it can be mined somewhat more cheaply, it is believed by some that it will eventually replace chrysotile for many uses.

The demand for asbestos as a war material has overshadowed its demand for peaceful industrial uses. Little is written in regard to its use in war, although it is doubtless finding a wide use in the various types of war vessels, from submarines to superdreadnaughts.

United States

According to Diller[1] the production of asbestos in the United States in 1916 was 1479 short tons as compared with 1731 tons in 1915. The price ranged from $15 to $1000 per ton as compared with $10 to $400 in normal times. The imports during 1916 amounted to 116,162 short tons, making a total of 117,641 tons available for the manufacturers of asbestos in the United States. Although this country is a small producer of raw asbestos, it is one of the largest manufacturers of asbestos goods.

The most productive deposits at the present time are in Arizona and Georgia. All the high-grade fiber comes from Arizona. Three other states, California, Idaho, and Virginia, recorded a small production.

Arizona.—The asbestos deposits of Arizona were opened in 1914 and have yielded since that time a small production of high-grade fiber. Their distance from railroad and their inaccessibility has delayed their development. The asbestos occurs as horizontal veins in dolomitic limestone, which has been altered by the intrusion of diabase. The small percentage of iron which this asbestos contains makes it of special value as an insulating material. The best grade of fiber obtained is of the finest textile quality.

California.—Low-grade asbestos of the serpentine variety has a wide distribution in California, but so far there has been only a small production. When the market demands it, this State is capable of supplying a large amount of low-grade fiber. According to Diller[2] three carloads of asbestos was produced on Mears Creek, near Sims, in Shasta County, and shipped to an asbestos factory in Oakland.

Georgia.—Georgia has for more than 20 years produced asbestos and at present it is yielding the bulk of the low-grade fiber produced in the United States. The Georgia asbestos is of the amphibole type, occurring as mass fiber forming the rock mass, and as slip fiber veins. It has a wide distribution in north and northeast Georgia, but is being mined at only one place at present—near Sal Mountain, north of Gainesville. The fresh rock is hard and the fibers are so closely packed that they are difficult to separate; when weathered, however, the rock becomes discolored,

[1] J. S. Diller, Asbestos, U. S. Geol. Surv. *Bull.* 666-H, 1917.
[2] *Op. cit.*

but the fibers are easily separable. When milled the hard rock yields a better colored, but shorter fiber, whereas the weathered rock yields a yellowed, but longer fiber. The asbestos is obtained from shallow open pits, and upward to 90 per cent. of the rock handled is marketed. The Georgia asbestos is of value for asbestos cement and other uses of low-grade fiber.

Idaho.—Asbestos of the mass fiber, amphibole variety, is found near Kamiah, Lewis County, Idaho. A relatively large amount of fiber of a low grade, suitable for fireproof cement and paint, is present there, and during the past year these deposits have been worked in a small way by a single company for local consumption.

Vermont.—The southern continuation of the asbestos-bearing belt of Canada extends into northern Vermont. Although the highest-grade spinning fiber is not found in paying quantities in this State, there is a large amount of the lower-grade fiber present which could be put on the market whenever the trade conditions demanded it. A mill was built near Mount Belvedere some years ago, but it was not operated for any length of time, and for some years there has been no production from that area.

Wyoming.—The asbestos deposits near Casper, Wyo., continue to attract attention, but the absence of high-grade fiber has prevented any substantial effort being made to develop them.

ASBESTOS IMPORTED INTO THE UNITED STATES IN 1916
(Figures furnished by Bureau of Foreign and Domestic Commerce, Department of Commerce)

Country.	1915.			1916.		
	Unmanufactured.		Manufactured (Value).	Unmanufactured.		Manufactured (Value).
	Quantity (Short Tons).	Value.		Quantity (Short Tons).	Value.	
Austria-Hungary	....	....	$10,502	....	....	....
British South Africa	....	....	....	112	$10,625	....
Canada	93,565	$1,980,749	1,867	114,978	3,069,617	$1,841
Colombia	....	....	....	....	....	109
Cuba	....	....	538	....	....	....
Denmark	....	....	49	....	....	....
England	....	....	106,412	1,072	223,228	119,123
France	....	....	139	....	....	10,762
Germany	1	734	14,117	....	....	100
Japan	....	....	....	....	....	298
Italy	....	....	2,624	....	....	2,538
Netherlands	....	....	190	....	....	....
Scotland	....	....	879	....	....	293
	93,566	$1,981,483	$137,317	116,162	$3,303,470	$135,064

Foreign Countries

Canada.[1]—The asbestos industry of Canada was particularly active during 1916, and the value of the production was the highest on record,

[1] *Eng. Min. Jour.*, March 17, 1917.

although the quantity was slightly exceeded in 1913. Stocks on hand were much reduced. The production was confined, as usual, to the asbestos districts of Black Lake, Thetford, Robertsonville, Danville, and East Broughton, in the eastern townships of Quebec; in January of 1917, however, the first shipment of asbestos produced in Ontario was made. The production in Ontario was from the township of Deloro in the Porcupine gold district and was made by D. M. Forbes and Edward Slade, two former operators in the Thetford district.

OUTPUT AND VALUE OF CANADIAN ASBESTOS IN 1915 AND 1916[1]

	1915.		1916.	
	Crude.	Milled.	Crude.	Milled.
Output, tons	3,987	102,572	5,414	112,832
Sold, tons	5,370	105,772	5,893	130,123
Value, tons	$1,076,297	$2,476,869	$1,867,064	$3,266,268
Average per ton	$200.43	$23.42	$316.82	$25.10

The total output in 1916 was 118,246 tons which, compared with 106,559 tons in 1915, shows an increase of 11 per cent.

Stocks on hand Dec. 31, 1916, were reported as only 6081 tons, as compared with 24,345 tons Dec. 31, 1915, and 31,171 tons Dec. 31, 1914. Sales of asbestic in 1916 were 18,500 tons.

The total quantity of asbestos rock sent to mills during the year was 1,822,461 tons, from which was obtained 112,832 tons of fiber, or an average recovery of 6.20 per cent.

Queensland.[2]—The asbestos deposits of Queensland are in its eastern part near Rockhampton and are associated with the Cawarral-Canoona serpentine belt which extends from Balnagowan near Fitzroy River to Marlborough in the direction of Broadsound. This area contains asbestos deposits in a number of localities, as at Tungamull, Mount Wheeler, Mount Etna, Morinish, Princhester, and Marlborough. Asbestos is also found in serpentine in the Kilkivan district of Mount Muir and Black Snake, in the Kandauga district near the Blue Bell copper mine and near Nodonga Creek to the south-southwest of Gympie, and at Eddystone to the north of Mitchell in the Noranoa district. At Mount Pring, close to Bowen, a serpentine belt has recently been discovered showing the presence of asbestos in small quantities. The deposits at Princhester and Marlborough appear to be of most importance, although little is known of the value and extent of any of them.

About 9 miles north-northeast of Princhester asbestos has been found in mountainous country north of Paddock Creek, about 4 miles from the

[1] Preliminary report of mineral production of Canada for 1916; *Eng. Min. Jour.*, March 17, 1917.
[2] B. Dunstan, *Queensland Govt. Min. Jour.*, Aug. 15, 1916.

railway now under construction from Rockhampton to St. Lawrence. Some years ago mining operations in this locality revealed numerous veins of soft asbestos along a face of decomposed serpentine 20 ft. wide, but the thickness of the decomposed rock forming the overburden evidently discouraged the prospectors and the work was abandoned.

Twelve or 13 miles south-southeast of Marlborough asbestos veins occur in the area bounded by Devlin and Marlborough Creeks and the Fitzroy River. On Marlborough Creek, near its junction with the Fitzroy River, asbestos veins in serpentine are said to be numerous, silky, clearly defined, and to contain fiber 1½ in. long. The serpentine at Mount Pring, which is associated with diorite dikes and granite masses, was found to contain at the only place examined small veins of fine silky asbestos. The position is about 2 miles from the Ayr-Bowen Tramline and about 12 miles by road from Bowen, the serpentine being exposed on one of the steep spurs on the southwestern side of the mountain.

So far there has been no commercial production of asbestos in Queensland.

Russia.—Asbestos is found in three widely separated districts of Russia: in the Ural Mountains principally near Ekaterinburg, in the Bogolsof mining district, and near Orenburg; in the Caucasus Mountains near Kutais and Shusha; and in south-central Siberia near Irkutsk. About 99 per cent. of the Russian output comes from the Ural Mountains and about one-third of that comes from the Ekaterinburg district. Six companies in the Urals have joined the syndicate of Ural asbestos producers, representing a total annual output of more than 18,000 tons. Some of the best asbestos mined in the Urals is produced at mines 60 miles northeast of Ekaterinburg in a zone of serpentine rocks about 6 miles long and about 1400 yd. broad. The quality of the asbestos is believed to be as high as that of Canada. The asbestos mining in the Urals is primitive in character, but in some cases the production is being made more systematic.

OUTPUT OF THE URAL (EKATERINBURG) ASBESTOS

Year.	Short Tons.	Year.	Short Tons.
1906	8,001	1910	10,936
1907	8,743	1911	15,872
1908	10,694	1912	16,584
1909	13,129	1913	16,661

According to official statistics the exports before the war were shipped by way of Riga to Germany, Austria, United Kingdom, Belgium, and Netherlands.

EXPORTS OF ASBESTOS FROM RUSSIA

Year.	Short Tons.	Year.	Short Tons.
1909	9,160	1913	13,669
1910	9,689	1914	8,577
1911	13,524	1915	975
1912	15,547		

South Africa.—There are two kinds of asbestos found in South Africa, crocidolite or blue asbestos and chrysotile or serpentine asbestos. Crocidolite, which was actively mined during the past year, comes from Cape Province and crysotile comes mainly from Rhodesia.

Frood[1] has contributed an interesting article on the asbestos industry in the Cape Province. He states that blue asbestos is found in the lower Griquatown beds, which forms the range of hills known as the Asbestos Mountains. It is found over a distance of 300 miles in Kuruman, Hay and Prieska districts of the Cape, in a belt of 4 miles or more in width stretching north from 30 miles south of Prieska. This he considers the largest asbestos-bearing area in the world. Throughout this area the asbestos deposits are found to occur in greater or less abundance; there are small stretches in which it has not been opened up, but so far as known the belt is continuous.

The richest occurrences so far opened up to any considerable extent are those near Koegas, on Orange River. From Koegas to the Bechuanaland border, 130 miles to the northeast, occasional properties are being worked. From the Bechuanaland border to Kuruman there is a succession of asbestos properties, and even from the latter to Tsenin there is little ground which has not been taken up by lease or prospecting title.

The only mines on which considerable work has been done are those of the Cape Asbestos Co. at Koegas and Westerberg, where regular methods of tunneling along the almost horizontal beds are employed. Underground workings of limited extent have been carried on at Naauwpoort and Elandsfontein in Hay district, at Wonderwerk and Bretby in Kuruman district. Elsewhere the recovery is obtained from surface quarries.

Crocidolite is a sodium-iron silicate containing little water, whereas chrysotile is a magnesium silicate containing much water. Chrysotile is said to withstand a temperature of 5000° F., whereas crocidolite is easily decomposed with heat, and therefore the former is of greater value where heat resistance is required. The fiber of crocidolite, however, is said to be lighter, finer, longer, stronger, and more elastic than that of

[1] G. E. B. Frood. The Cape Asbestos Industry: *So. Afr. Min. Jour.*, pp. 94–95, Sept. 30, 1916; pp. 127–128, Oct. 7.

chrysotile and also to possess a greater efficiency as a heat and electric insulating material. It is said also to be unaffected by moisture, ordinary acids, and by sea water. As it can be mined at a lower cost than chrysotile, since the yield per ton of rock handled is greater, it is believed that it may eventually divide the market, if not monopolize it, for certain industrial uses for which it is particularly suited, as the marked increase in its production during 1916 seems to indicate.

Serpentine asbestos, chrysotile, is found in Rhodesia and Transvaal. That the mining of asbestos in Rhodesia was active during 1916 is indicated by the production during May of the year of 551.4 tons, valued at £8792. The total output of asbestos for the year is not known.

ASPHALT

By Clifford Richardson

Asphalt should be regarded, in the strictest sense, as a more or less solid form of native bitumen. In the United States residual pitches of similar consistency, which are produced from asphaltic petroleums by the removal of their more volatile components by distillation, are known as artificial or manufactured asphalt, and the designation has been extended, commercially, in recent years to the more or less liquid residuals of these petroleums which are used in or on road surfaces. The term, therefore, has acquired a very general industrial use. It includes all forms of bitumen, native and manufactured, which are employed in pavement and road construction, as well as the solid native bitumens gilsonite and grahamite, which, in a strict sense, are sharply differentiated from asphalt.

In Great Britain, on the contrary, a sectional committee on road material and a sub-committee on bituminous materials of the Engineering Standards Committee, have taken an entirely different position in regard to the meaning of the terms asphalt and bitumen. As this report is not generally available in this country, that portion of it relating to bitumen and asphalt may well be reproduced here, for the information of the engineer and all who are interested in modern method of road construction.

BITUMENS AND ASPHALTS

4. Definition of Bitumen

"Bitumen is a generic term for a group of hydrocarbon products soluble in carbon disulphide, which either occur in nature or are obtained by evaporation of asphaltic oils. The term shall not include residues from paraffin oils or coal-tar products."

Note.—"Commercial materials may be described as bitumen if they contain not less than 98 per cent. of pure bitumen as defined above."

5. Definition of Native Bitumen

"Native bitumen is bitumen found in nature, carrying in suspension a variable proportion of mineral matter."

"The term 'native bitumen' shall not be applied to the residuals from the distillation of asphaltic oils."

6. Definition of Asphalt

"Asphalt is a road material consisting of a mixture of bitumen and finely graded mineral matter. The mineral matter may range from an impalpable powder up to material of such a size as will pass through a sieve having square holes of ¼-in. size."

7. Definition of Native or Rock Asphalt

"Native or rock asphalt is a rock which has been impregnated by nature with bitumen."

8. Prefixes Denoting Source of Origin

"The Committee recommended that for convenience of identification prefixes denoting geographically the source of origin should be attached to each of the four terms defined above."

From an American point of view it is difficult to see anything reasonable in the proposed definition of asphalt, for although it might be applied, as the British Committee states, to a surface consisting of a mineral aggregate the largest particles in which will pass a sieve having square holes ¼ in. in size, what would a surface be denominated which contained particles of stone of a size retained on a ¼- and passing ½-in. mesh, a vast area of which has recently been laid in this country?

The British proposals seem untenable from an American point of view. They have, of course, arisen from the fact that the first acquaintance with asphalt pavements in Great Britain was with surfaces constructed with rock asphalt, a limestone impregnated with bitumen.

The attitude of the United States Geological Survey, in this connection, may be seen from the opening paragraph of a report by Mr. John D. Northrup, in *Mineral Resources of the United States*, 1915, Part II, page 135, on "Asphalt, Related Bitumen and Bituminous Rocks in 1915" where he says:

"In a broad sense the term natural asphalt may be used to denote all types of naturally occurring asphaltic substances that are employed in the arts and industries. It is so used in this chapter in reference to the asphaltic materials commercially mined or quarried in the United States. They comprise the native bitumens maltha, grahamite, and gilsonite; the so-called "pyrobitumen" elaterite; the bitumen impregnated rocks, sandstone, limestone, and shale; and the cerous hydrocarbon, ozokerite. The term "manufactured asphalt," as used in this chapter, includes both oil asphalt, a solid or semi-solid by-product obtained in the distillation of asphaltic and semiasphaltic petroleum, andu residal asphaltic oils or pitches, the viscous residues of the evaporation or distillation of petroleum of asphalt base to a point where all the burning oils and often some of the heavier distillates have been removed."

Commercial Sources of Asphalt in the United States

While the native asphalts are widely distributed in the United States, both in a more or less pure form and as associated with mineral matter, the localities where deposits exist which are of commercial inportance are, as in former years, limited. The only occurrences of solid native bitumen of any commercial importance at the present time are those found in Utah, gilsonite and ozokerite. Grahamite, heretofore obtained from similar fissure veins in Oklahoma, has been practically exhausted. The sands which are impregnated with bitumen and occur on such a large scale in California and in Kentucky have been demonstrated to be of only local importance and are now worked on a reduced scale, as will appear from the accompanying data.

Artificial or Manufactured Asphalt

The artificial or manufactured asphalts continue to be produced in large amounts in the United States, being the residuals from the distillation of crude asphaltic and semiasphaltic petroleums, the principal source being the oils of the mid-continental, Texas and Illinois fields. From the California asphaltic petroleums material of the consistency suitable for surface application upon country highways, and of harder consistency for paving purposes is prepared, but this supply does not reach the Eastern market because of the freights involved in transporting it to such a distance, on which account it cannot enter into competition with the residuals prepared from crude Mexican petroleum which is available for the same purpose as it is received on the Atlantic Coast. Although the crude Mexican material must be regarded as an imported article, the residual asphalt made therefrom is a domestic product, or by-product. After the removal of the tops from this oil some disposition must be made of the residuals and, consequently, they must be disposed of at more or less of a sacrifice as a by-product. As such, it is, naturally, quite variable in quality, dependent upon the heat to which it is subjected in the distillation. Experience has, however, developed means of producing a material of higher grade at the present time than in former years. These residuals are very susceptible to any high temperatures which may be met in their handling and the result is that pavements into which they enter as a binding material differ in a marked degree in their character.

According to the U. S. Geological Survey in *Mineral Resources of the United States* residual asphalt of domestic origin in 1915 amounted to 664,503 short tons, to which a value of $7.10 per short ton is given; but this valuation is very much greater, in the light of the writer's information, than could be obtained in the market. Considering the fact, as shown in a quotation from *Mineral Resources of the United States* for 1915 that much of this so-called asphalt includes "the viscous residues of the evaporation or distillation of petroleum of asphalt base to a point where all the burning oils and often some of the heavier distillates have been removed," of course such material cannot strictly be included under the term asphalt.

It is difficult to determine to what uses this large supply of material was applied. A certain amount was, no doubt, used for pavements and roads, for waterproofing and for saturating felts, but by no means all of it. The discrepancy may be explained by the fact that the stated output includes 417,859 tons of asphaltic oil, used for road-sprinkling purposes. The production is, therefore, only 246,644 short tons of material of the character of a residual pitch. To this the Survey assigns an average price of $9.42 per ton which seems to be high for 1916 and represents merely an asking price.

The total sales in 1916 of manufactured asphalt derived from domestic petroleum amounted to 688,334 short tons, valued at $6,178,851. Of this quantity 404,009 tons, valued at $3,158,603, consisted of road oils and fluxing material, and 284,325 tons, valued at $3,020,248, consisted of solid or semisolid products utilized for paving.

California led all other States in the production of manufactured asphalt, its output from sixteen refineries in 1916 amounting to 257,930 short tons, valued at $1,958,946, and consisting of 108,228 tons of road oils and fluxes, valued at $633,579, and 149,702 tons of paving residuals, valued at $1,325,367.

PRODUCTION OF ASPHALT BY VARIETIES
(In short tons)

Variety.	1914.		1915.		1916.	
	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.
Bituminous rock Maltha	51,071	$162,622	44,329	$157,083	....	....
Wurtzilite (elaterite) Gilsonite	19,148	405,966	20,559	275,252	....	....
Grahamite	9,669	73,535	10,863	94,155	....	....
Total	79,888	642,123	75,751	526,490	98,477	923,281
Manufactured or oil asphalt (c)	360,683	3,016,969	664,503	4,715,583	688,334	6,178,851
Total	438,271	3,647,692	740,254	5,242,073	786,811	7,102,132

(c) This item includes material previously referred to as refined bitumen.

State.	1913.		1914.		1915.	
	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.
California	27,870	$69,825	28,186	$77,810	17,794	$61,485
Kentucky	(a) 17,465	(a) 60,131	(a) 18,935	(a) 66,298	(a) 19,311	(a) 65,352
Oklahoma	16,459	91,416	9,669	73,535	16,907	118,351
Texas	(b)	(b)	(b)	(b)	(b)	(b)
Utah	30,810	529,341	23,098	424,480	21,739	281,302
Total	92,604	750,713	79,888	642,123	75,751	526,490

(a) Includes Texas. (b) Included in Kentucky.

The total sales in 1916 of manufactured asphalt derived from Mexican petroleum amounted to 572,387 short tons, valued at $6,018,851. Of the quantity sold, 295,682 tons, valued at $2,486,938, consisted of road oils and fluxes, and 276,705 tons, valued at $3,531,913, consisted of residuals utilized for paving.

MARKETED PRODUCTION OF NATURAL ASPHALT AND BITUMINOUS ROCK
(In short tons)

Year.	Quantity.	Value.	Year.	Quantity.	Value.
1883	3,000	$10,500	1900	54,389	$415,958
1884	3,000	10,500	1901	63,134	555,335
1885	3,000	10,500	1902	84,632	461,799
1886	3,500	14,000	1903	55,068	483,282
1887	4,000	16,000	1904	64,167	420,701
1888	50,450	187,500	1905	62,898	305,242
1889	51,735	171,537	1906	73,062	674,934
1890	40,841	190,416	1907	85,913	928,381
1891	45,054	242,264	1908	78,565	517,485
1892	87,680	445,375	1909	99,061	572,846
1893	47,779	372,232	1910	98,893	854,234
1894	60,570	353,400	1911	87,074	817,250
1895	68,163	348,281	1912	95,166	865,225
1896	80,503	577,563	1913	92,604	750,713
1897	75,945	664,632	1914	79,888	642,123
1898	76,337	675,649	1915	75,751	526,490
1899	75,085	533,904	1916	98,477	923,281

Uses

Asphalt, both native and manufactured, is employed in the United States on a large scale in the construction of asphalt pavements and road surfaces. As the result of the great demand for good or better roads, induced by the enormous increase in the amount of motor travel which has developed within the last decade, the demand for asphalt for their construction has grown enormously. The *Municipal Journal*[1] presents data showing that 19½ million yards of asphalt pavements of various types have been built in 361 cities in this country in 1916, classified as follows:

Sheet asphalt	9,744,673 sq. yd.
Bituminous concrete	5,987,172 sq. yd.
Bitulithic	3,838,145 sq. yd.

The amount of asphalt and asphaltic oils which have entered into the construction of country road surfaces has also been equally astonishing, although no definite data as to it are available.

Asphalt is also used on a large scale industrially in the manufacture of mastic of various types, for walks, especially in France, though not on any considerable scale in this country, as roofing, in the shape of felt

[1] Feb. 1 and March 29, 1917.

saturated with bitumen, as shingles, as insulating material, in the form of saturated burlap and asbestos, for waterproofing and damp courses, as paint, pipe coating and as a slushing compound, as a component of a putty for repairing leaks in roofs, as a caulking material, and for other purposes too numerous to mention, the application to which it is suitable increasing to a marked degree every year.

Imports

With the exception of small amounts of European asphaltic limestones, some manjak from Barbados and grahamite from Cuba, the main imports of asphalt into the United States in 1915 were from the well-known asphalt lakes of Trinidad and Venezuela, which amounted to over 100,000 tons. The character of these native asphalts has shown the same uniformity presented in previous years, the demand for them continuing because of the reliance which service in the past has demonstrated can be placed upon these materials, in spite of the competition of the cheaper residuals.

Data in regard to imports are presented in the following form by the U. S. Geological Survey.

ASPHALT IMPORTED INTO THE UNITED STATES DURING THE FISCAL YEARS ENDING JUNE 30, BY COUNTRIES

(Long tons)

Imported from	1914.		1915.		1916.	
	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.
Europe:						
Belgium	....	....	....	....	....	....
France	....	....	100	$1,317	....	....
Germany	1,311	$10,216	913	6,909	....	....
Italy	50	294	689	4,621	....	....
Netherlands	....	....	....	....	....	....
Switzerland	785	5,032	640	4,304	195	1,197
United Kingdom	5,132	13,128	1,065	12,214	763	8,768
North America:						
Canada	1	20	32	207	119	1,789
Mexico	109	1,532	79	1,129	18	399
West Indies:						
British	97,666	444,413	55,771	327,047	95,923	511,375
Cuba	668	10,866	490	12,189	570	13,409
Danish	....	....	....	....	....	....
South America:						
Colombia	113	6,894	19	1,057	....	....
Venezuela	74,849	425,060	23,313	117,760	32,645	165,190
Asia:						
Turkey	5	932	12	2,497	....	....
Oceania	....	....	....	....	1	10
Total	180,689	918,387	83,123	491,251	130,234	702,137

WORLD'S PRODUCTION OF ASPHALT AND BITUMINOUS ROCK (*a*)

(In metric tons)

Asphalt.

Year.	France.	Germany.	Hungary.	Italy. (*c*)	Spain.	Trinidad. (*b*)	United States. (*e*)	Total.
1906...	28,231	138,059	4,111	34,386	6,229	132,381	44,430	387,827
1907...	33,000	126,649	3,920	38,568	8,643	147,051	36,656	394,487
1908...	41,000	89,009	4,818	34,761	9,231	136,583	37,389	352,791
1909...	44,800	77,537	5,054	39,165	6,582	146,013	39,640	358,791
1910...	38,500	81,208	4,994	41,705	8,473	161,587	31,159	367,626
1911...	38,000	81,902	3,861	50,179	3,495	163,080	40,307	380,824
1912...	31,535	96,112	4,460	52,707	5,387	176,077	37,570	403,888
1913...	30,892	....	3,024	56,750	5,582	208,164	31,810	....
1914...	....	....	....	38,778	....	....	26,147	....
1915...	....	....	....	31,456	....	....	28,506	....

Bituminous Rock.

Year.	Austria.	France.	Hungary.	Italy.	Spain.	United States.	Total.
1906........	2,840	196,375	34,664	130,825	7,794	21,848	394,346
1907........	3,858	177,000	33,096	161,126	8,219	41,301	424,600
1908........	3,695	171,000	72,972	134,163	12,373	33,901	428,104
1909........	2,975	169,000	(*d*)70,000	111,067	5,284	50,243	408,569
1910........	1,066	170,000	(*d*)70,000	162,212	7,795	58,581	469,654
1911........	1,740	169,697	(*d*)60,000	188,133	6,500	38,704	464,774
1912........	4,234	312,000	(*d*)50,000	181,397	....	49,691	....
1913........	3,026	324,610	45,860	171,097	....	(*f*)52,220	....
1914........	....	....	....	119,853	....	44,257	....
1915........	....	....	....	47,650	....	40,210	....

(*a*) Statistics of production in Barbados, Cuba, Mexico, Russia, Switzerland, and Venezuela are not available. (*b*) Exports. (*c*) Including mastic and bitumen. (*d*) Estimated. (*e*) Previously the U. S. statistics included oil asphalt. This is now omitted, leaving only the natural asphalt. (*f*) Includes some maltha.

TOTAL EXPORTS OF ASPHALT FROM TRINIDAD, 1910–1914

(In long tons)

Year.(*a*)	To United States.			To Europe.			To Other Countries.			Grand Total.
	Lake.	Land.	Total.	Lake.	Land.	Total.	Lake.	Land.	Total.	
1910..........	109,198	9,274	118,472	65,778	150	65,928	......	......	......	184,400
1911..........	103,590	8,040	111,630	67,105	......	67,105	983	......	983	179,718
1912..........	95,111	8,600	103,711	85,299	......	85,299	486	......	486	189,496
1913..........	123,873	1,400	125,273	104,153	......	104,153	605	......	605	230,031
1914..........	67,357	2,950	70,307	75,297	......	75,297	......	......	......	145,604

(*a*) Ending Jan. 31 of year succeeding.

ASPHALT IMPORTED FOR CONSUMPTION INTO THE UNITED STATES

(In short tons)

Year.	Crude.		Dried or Advanced.		Bituminous Limestone.		Total.	
	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.
1908	137,808	$532,297	7,642	$67,364	6,224	$20,758	151,674	(*a*) $624,979
1909	128,109	511,631	10,087	94,146	6,409	18,440	144,605	(*a*) 633,205
1910	162,435	588,206	20,180	178,704	3,696	9,301	186,311	(*a*) 785,963
1911	167,681	572,198	20,461	184,954	8,180	23,468	196,322	789,236
1912	193,645	726,345	20,707	177,992	3,976	15,808	218,328	921,145
1913	(*b*) 207,033	738,452	(*c*) 14,750	133,336	6,395	38,823	228,178	910,611
1914	137,352	664,558	*Nil.*	....	1,705	11,060	139,057	675,618
1915	123,426	680,537	*Nil.*	....	*Nil.*	....	123,436	680,357
1916	131,616	733,307	*Nil.*	....	295	1,795	131,911	735,102

(*a*) Imports for 1908 include $4560 of manufactures, 1909, $8988; 1910, $9752. (*b*) Includes dried or advanced asphalt for last 3 months of 1913. (*c*) Last 3 months of 1913 included in crude asphalt.

Bituminous Sands

The bituminous sands which have been known for a number of years to exist in Northern Alberta, have been examined recently in greater detail. They occur in inexhaustible quantities and are similar in character to those found in Kentucky, California and elsewhere in the United States. Experimental pavements have been constructed with them in Edmonton to demonstrate their suitability for pavement construction. The chief interest in this material will depend upon its economic relations, that is to say, whether it can be mined and transported at such a figure as to make its use possible. In the light of experience with other material of this description in the United States, this would seem hardly probable. The occurrence and location of these sands are described in *The Canadian Mining Journal* for Feb. 1, 1916, page 73.

Honduras

The occurrence of a deposit of pure bitumen or asphalt in the vicinity of Juticalpa in Honduras has been described in the *U. S. Consular Reports,* as being at a considerable distance from the Pacific port of Amapala. As to the commercial value of the deposit no data are available.

Ozokerite

The ozokerite deposits of Utah have been examined by a representative of the U. S. Geological Survey in 1916, and the results published in *Bulletin* No. 641-A. In view of the lack of availability of the Galician supply, because of the continental war, renewed interest has been taken in that from domestic sources.

Anniversary.—The year 1916 is marked in the asphalt industry by being the fortieth anniversary of the first construction on any large scale of a sheet asphalt pavement, composed of sand, dust and Trinidad lake asphalt, the first example of this type having been laid on Pennsylvania Avenue, in Washington, D. C. in 1876, from which has developed the great industry which exists today.

BARIUM AND STRONTIUM

Barytes

Readjustment of the barytes industry in the United States owing to the war progressed further in 1916 along the same lines as in 1915. Domestic production increased greatly, due in part to virtual stoppage of imports, but even more to greater demands and higher prices. Total imports were 26,025 tons in 1914; 3460 tons in 1915; 149 tons in 1916. In the same years production was respectively 52,747 tons, 108,547 tons, and 200,000 tons. In previous years the cost of imported barytes, which was of slightly better grade than the domestic, was no greater than the cost of producing domestic barytes on the Atlantic seaboard. Now sufficient supplies of foreign product are not to be obtained at any price.

At the beginning of 1917 the Foote Mineral Co. quoted ground barytes (99 per cent.) at $18 per ton for carload lots, commercial lump at $10 per ton, bleached white powder 1¼ cts. per lb., blanc fixe 3½ cts. per lb., and dioxide 30 cts.

PRODUCTION OF CRUDE BARYTES IN THE UNITED STATES, BY STATES, IN SHORT TONS

State.	1913.			1914.			1915.		
	Quantity.	Value.	Average Price per Ton.	Quantity.	Value.	Average Price per Ton.	Quantity.	Value.	Average Price per Ton.
Georgia	(a)	(a)	(a)	(a)	(a)	(a)	31,027	$102,825	$3.31
Missouri	31,131	$117,638	$3.78	33,317	$112,231	$3.37	39,113	158,597	4.05
Tennessee	(b)2,098	3,568	1.70	10,113	16,273	1.61	25,074	71,390	2.85
Kentucky							7,753	28,427	3.67
Other States(c)	12,069	35,069	2.91	9,317	27,143	2.91	5,580	19,793	3.55
Total	45,298	156,275	3.45	52,747	155,647	2.95	108,547	$381,032	3.51

(a) Included in other states.
(b) Production of Tennessee; no production of barytes reported for Kentucky in 1913.
(c) Includes, 1913: Georgia, North Carolina, South Carolina, and Virginia; 1914: Alabama, California, Georgia, North Carolina, South Carolina, and Virginia; 1915: Alabama, Alaska, California, North Carolina, South Carolina, and Virginia.

An article by Arthur C. Vivian[1] describes barytes mining in Georgia, particularly in the vicinity of Cartersville, Bartow County. The result of the boom there has been the starting up of a large number of individual mining ventures on a small scale. On account of the probable temporary nature of the great demand, this seems the most logical de-

[1] *Eng. Min. Jour.*, **102**, 1083.

velopment. It is made possible by the nature of the deposits, which permit of cheap open-cut methods. They occur in a deep mantle of residual clays, distributed irregularly in sizes varying from small grains to huge boulders. The mineral is easily separated from the clay, giving a product of 98 to 99 per cent. $BaSO_4$. The separation is effected by the use of log washers, preceded and followed by hand picking. The small material is usually further dressed in plunger-type jigs. In one place an old flour mill has been turned into a mill for dressing and refining barytes. There the fine material is leached with sulphuric acid to remove iron and other impurities.

PRODUCTION OF CRUDE BARYTES

	Short Tons.		Short Tons.		Short Tons.
1900	67,680	1906	50,231	1912	37,478
1901	49,070	1907	89,621	1913	45,298
1902	61,668	1908	38,527	1914	52,747
1903	50,397	1909	61,945	1915	108,547
1904	65,727	1910	42,975	1916	
1905	48,235	1911	38,445		

IMPORTS OF BARIUM PRODUCTS
(Fiscal year, ending June 30)

Product.	1915.		1916.	
	Quantity.	Value.	Quantity.	Value.
Baryta, sulphate of, or barytes including baryta earth:				
Unmanufactured tons (2240 lb.)	9,616	$21,087	15	$245
Manufactured tons (2240 lb.)	1,755	14,997	*Nil.*	*Nil.*
Blanc fixe, or artificial sulphate of barytes, and satin white, or artificial sulphate of lime, pounds	2,233,369	25,748	492,723	11,523
Lithopone, pounds	6,205,245	195,828	5,122,083	414,573
Barium carbonate, pounds	844,588	7,864	6	2
Barium binoxide, pounds	4,084,144	311,262	546,442	48,451
Barium chloride	4,686,029	60,532	50	10

The chapter on barytes and strontium in 1915 which appears in *Mineral Resources of the United States* for that year is the most elaborate which the Survey has published on this subject. In addition to its usual scope, it covers the uses and manufacture of barium products. It also contains a map showing the location of deposits of barytes and strontium ore and works manufacturing barium products in the United States and Alaska. The extension is stated to be due to the many inquiries received from consumers.

Foreign Countries.—Germany is known to have unlimited deposits of barytes which are probably of the highest grade of any in the world. They are believed to be using these partly in place of pyrites in the making of sulphuric acid. Data are of course unavailable at present.

Great Britain has extensive deposits of a good grade. The normal production is about 50,000 tons annually, and this has increased considerably during the war. In 1916 the production was 100,000 tons. The deposits are located principally in the north of England, but one of the best is at Larn, Ireland. The only economic deposit of witherite (barium carbonate) is located at Fourstones, Northumberland County. It is owned and operated by the Hedworth Barium Co., Ltd.

Canada has a number of good deposits. At present the production is small, but increasing.

Norway has a small production of barytes as a by-product of lead mining.

There is a large supply of barytes in the vicinity of Pulantien, Manchuria. Recently Japanese residents there have formed the Manchurian Barium Co., to fill large orders from Osaka. The Japanese demand is good.[1]

There are large deposits in Rhodesia, which have been examined by the Geological Survey of South Africa. If the local demand continues there, mining operations will in all probability be started in the near future.[2]

STATISTICS OF BARYTES IN THE PRINCIPAL COUNTRIES
(Metric tons)

	1912.	1913.	1914.	1915.	1916.
Austria-Hungary (exports)					
Barium chloride	3,659	4,918	....	....	....
Barytes	2,690	753	....	....	....
Belgium (production)	32,400	12,000	....	....	....
Canada (production)	421	582	555	499	1,241
France (production)	13,620	12,236	....	....	....
Baden (production)	15,871	16,445	....	....	....
Bavaria (production)	27,199	27,199	....	....	....
Germany (exports)					
Barytes	142,681	158,065	....	....	....
Barium white	8,242	7,647	....	....	....
Barium chloride	8,096	5,649	....	....	....
Barytes (imports)	18,666	19,466	....	....	....
Italy (production)					
Barytes, crude	13,420	12,970	12,970	17,850	....
Barytes (imports)	1,986	1,771	1,409	1,319	1,398
Barytes (exports)	381	234	210	3,288	2,755
Spain (production)	1,096	....	....	....	....
Sweden (imports)	644	610	....	....	....
United Kingdom (production)	43,453	48,792	49,718	63,483	....
United States (imports)	27,093	37,490	26,025	3,460	149
United States (production)	34,009	41,105	47,865	98,500	....

Strontium

Strontium, or rather the commercial salts of strontium, began to occupy considerable attention in the United States during 1916. Normally the consumption in this country has been about 2000 tons per

[1] *Comm. Rept.*, April 21, 1917.
[2] *So. Afr. Min. Jour.*, Sept. 2, 1916.

year, chiefly of the sulphate (celestite), and this was used almost wholly in the pyrotechnic industry. In Europe, however, large quantities of strontium hydroxide, which is made by calcining the carbonate (strontianite), have been used in the "strontia process"[1] in the manufacture of beet sugar. The U. S. Geological Survey states that Germany and Russia each use 100,000 tons per year for this purpose.

The United States' supply has come in the past from Germany and later from England. Both these sources have been stopped, England having placed an embargo on strontium salts. In the early part of the year users of strontium minerals found that the stock in this country had become very low. In addition to this, manufacturers of sugar began to show some interest in strontium. The strontia process is stated to effect a saving of 6 to 8 per cent. of the saccharine content of the molasses over the present methods; with a continuance of the high price of sugar, it seemed that an available supply of strontium hydroxide in this country might make profitable the adoption of the strontia process here. Strontium nitrate, into which form the sulphate is converted for use in pyrotechnics, and which is therefore the chief commercial salt in this country, increased in price from 6½ to 54 cts. per lb.[2]

With the above contributing causes there was awakened an interest in United States strontium deposits. Strontianite is the more valuable of the two commercial minerals because it is more readily converted into the desired salts. The extensive German deposits are of this mineral. But no important deposits of it have been found in this country. Celestite, however, has been found in many States, and there is potentially an abundant supply. The Geological Survey reports that some of this ore was produced and marketed in the United States during 1916 for the first time in many years. Most of it came from Arizona and California. Some was mined, but not marketed, in Washington. The output amounted to about 200 tons. The value is not stated. In normal times the ore, which should contain at least 95 per cent. $SrSO_4$, brings $12 to $14 per ton in the East.

Bulletin 540-T of the U. S. Geological Survey enumerates various deposits of celestite. One in Arizona has supplied ore for a nitrate plant at Long Beach, Cal. According to an article by D. F. Irvin on the strontium nitrate industry,[3] a plant at Los Angeles obtains its supply from a deposit in Imperial valley, southern California. The article describes in detail the preparation of the nitrate from celestite. The industry is described as a new war industry, and its future is stated to depend on the duration of the war.

[1] This process, together with the barium and other processes, is described in *Met. Chem. Eng.*, **16**, 440.
[2] *Min. Oil Bull.* (Los Angeles), Feb., 1917.
[3] *Min. Sci. Press*, **113**, 774.

BISMUTH

By Allison Butts

Bismuth is produced in the United States as a by-product in the refining of lead. The chief producers are the United States Metals Refining Co., who recover it by a liquation process from the anode slimes at the electrolytic lead refinery, East Chicago, Ind., and the American Smelting and Refining Co., who recover it at the lead plant at Omaha, Neb. The annual production is in the neighborhood of 200,000 lb.

No bismuth ore is mined in the United States. Another possible source is in the refining of blister copper from certain localities, which sometimes contains as much as 25 lb. bismuth per ton. A number of copper and lead ores in Colorado have bismuth ore associated with them, some parcels containing 15 to 25 per cent. bismuth, but the marketing or recovery of the bismuth has not been attempted on any large scale.

The United States continues to import considerable quantities, but the imports have declined somewhat since the development of domestic production. The following table gives the imports into the United States for the fiscal years since 1907: (*a*)

Year.	Quantity, Lb.	Value.
1907	215,647	$262,775
1908	225,833	313,919
1909	176,729	274,662
1910	200,221	316,838
1911	178,298	321,360
1912	166,980	305,282
1913	151,030	257,176
1914	133,190	241,448
1915	34,237	72,587
1916	64,821	155,925

(*a*) Dept. of Commerce.

The price of bismuth in this country is generally believed to be controlled by a European syndicate which receives practically all the shipments of the South American and Australian bismuth ores. The price declined during 1916 from $4.00 per lb. to $3.25 per lb. for large lots. The average price of the metal in London was given at 10s. per lb. in 1915 and 11s. in 1916. The only known buyer of bismuth ore in the United States, apart from brokers, is the American Smelting and Refining Co. There are numerous brokers who handle the ore, among them

E. Schaaf-Regelman, 21 State Street, Battery Park Building, New York City, and David Taylor, Boston Building, Salt Lake City, Utah.

Foreign Production.—The principal bismuth producing country is Bolivia, which furnishes more than all the other countries combined: 4145 tons of ore had been yielded to the end of 1915, the output starting in 1904. The most important mines are those of Aramayo Francke and Co., at Tasna, who treat the ores at the company's smelter at Quechisla. The ores are associated with the tin and silver ores of that region, and the principal bismuth mineral contained in them is the sulphide, bismuthinite. Of less importance from a producing standpoint, but of unusual interest on account of the large proportion of native bismuth that they contain, are the ores from Huayni-Potosi, to the north of La Paz.

PRODUCTION OF BISMUTH ORE IN BOLIVIA

Year.	Quantity, Metric Tons.
1911	550
1912	478
1913	422
1914	460
1915	570

Peru has an important deposit of bismuth in the San Gregorio mine, 3 miles south of the Cerro de Pasco smelter.[1] The deposit is said to be capable of supplying the entire world's demand for many years. It is controlled by the European syndicate and in recent years its production has been limited by them to about 25 tons of bismuth metal per annum. The ore consists entirely of oxidized bismuth compounds, chiefly the arsenate. This was concentrated from a grade of 2 or 3 per cent. up to 18 or 20 per cent., producing middlings of 5 per cent. No ore is being mined at present, the production being obtained entirely by treatment of the accumulated middlings. These are given a chloridizing roast, followed by lixiviation with sulphuric acid. From the solution the bismuth is precipitated as sulphide and then smelted to the metal. Accordingly the metal instead of concentrate is being exported at the present time.

The other important bismuth deposits of the world are those of Australia. These are described by B. Dunstan, Chief Geologist of Queensland,[2] in an article which treats also the mineralogy, metallurgy, and uses of bismuth, discussing its various alloys and listing the compositions of many of them. The principal producing localities at present are those of Kingsgate, Whipstick (Jingera), Captain's Flat, and Cobar, all in New South Wales; and those at Bamford and Mount Biggenden in Queensland. There are also a number of lesser localities, including some in Tasmania and South Australia. In Tasmania bismuth is re-

[1] MINERAL INDUSTRY, **24**, 62 (1915).
[2] *Queensland Govt. Min. Jour.*, Jan. 15, 1917.

covered as a by-product in the treatment of copper ores. The Mount Lyell refinery has found it profitable to treat the electrolytic slimes for bismuth. In nearly all of the Australian deposits the metal is found in various forms in the same locality—native, sulphide, and oxidized compounds—and associated with various other minerals. The mining of the bismuth ores is carried on in conjunction with other mineral development, especially with wolfram and molybdenite mining. An exception to this is the Biggenden mine, where bismuth mineral is the only one taken.

PRODUCTION OF BISMUTH MINERALS IN AUSTRALIA
(Tons of 2240 lb.)

Year.	Queensland.	New South Wales.	Tasmania.
	Tons. (*b*)	Tons.	Tons.
1904	20.9	40.3	.....
1905	15.3	55.8	.....
1906	6.5	25.9	.....
1907	6.3	16.3	.....
1908	22.7	8.7	.....
1909	10.3	8.6	.....
1910	21.0	6.4	.....
1911	9.8	7.9	.....
1912	5.0	5.8	.....
1913	1.1	9.0	5.0
1914	0.9	15.0	5.6
1915	2.6	18.0 (*a*)	5.5
1916	3.6	30.0	3.5

(*a*) Estimated. (*b*) Exclusive of bismuth taken with tungsten.

Uses of Bismuth.—The United States production is taken very largely by manufacturers of drugs and medicines. The carbonate, the subnitrate and the oxychloride have an extensive use in medicine. The oxide and the subnitrate are used in the glazing and painting of porcelain and in glass staining, and also to a limited extent in pigments. Many organic compounds of bismuth are also used in medicine.

The only important use of metallic bismuth is in the making of alloys. Many fusible alloys, with melting points all the way down the scale to temperatures considerably below the boiling point of water, are made with bismuth. These alloys are used in various kinds of fuses, in soldering, and in obtaining definite constant temperatures, especially in tempering steel. Most of those which are fusible above 100° C. are alloys of bismuth, tin, and lead, while those fusing at lower temperatures contain cadmium, and the lowest mercury.

BORAX

J. W. Beckman

The west coast of the North American as well as the South American continent seems to be the only available source of borax, since the Turkish deposits are completely eliminated from influencing the conditions of the world, outside of Germany and its allies.

The Borax Consolidated, an English corporation, controls the world's commerce in borax and boron compounds. This company has refineries in various parts of the world and used to control the Turkish deposits prior to the world upheaval.

The war has been a boon to the development of the borax deposits in the United States. The main output of borax comes from California and the output increased in 1916 to 102,705 tons valued at $2,359,295 as compared with an output of 67,004 tons in 1915 valued at $1,663,521.

UNITED STATES IMPORTS OF BORAX, ETC.
(Fiscal years ending June 30)

Year.	Borax.		Borate of Lime, Etc.		Boracic Acid.	
	Pounds.	Value.	Pounds.	Value.	Pounds.	Value.
1911	7,319	$790	13,095	$2,277	343,094	$12,733
1912	6,409	604	22,784	3,856	276,496	10,540
1913	11,768	882	16,267	2,038	362,400	13,897
1914	466	64	220	29	527,201	22,390
1915	*Nil.*	....	*Nil.*	....	401,684	18,002
1916	*Nil.*	....	*Nil.*	....	424,219	22,145

PRODUCTION OF BORATE ORES IN CALIFORNIA (*a*)
(In tons of 2000 lb.)

Year.	Tons.	Value.	Year.	Tons.	Value.	Year.	Tons.	Value.
1902	(*b*)17,202	$2,234,994	1907	53,412	$1,200,913	1912(*d*)	42,315	$1,127,813
1903	34,430	(*c*)661,400	1908	22,200	1,117,000	1913(*d*)	58,051	1,491,530
1904	45,647	(*c*)698,810	1909	16,628	1,163,960	1914(*d*)	62,400	1,464,400
1905	46,334	1,019,158	1910(*d*)	42,357	1,201,842	1915(*d*)	67,004	1,663,521
1906	58,173	1,182,410	1911(*d*)	53,330	1,569,151	1916(*d*)	102,705	2,359,295

(*a*) Reported by the California State Mining Bureau. (*b*) Mostly refined borax, whence the apparent discrepancy in value. Output of the other years is given as crude material. (*c*) Spot value. (*d*) U. S. Geol. Survey, crude.

The Pacific Coast Borax Co. is the largest producer of borax in the United States and has extended its activities considerably. The Sterling Borax Co., situated in Los Angeles County, and the Russell Borax Co., in Ventura district, have both operated actively and made some extensions. The Stauffer Chemical Co. has been developing some deposits at Cuddy, Kern County.

The various waters in lakes situated in Oregon, as well as California, promise to yield considerable amounts of borax. They all contain borax in various concentrations, together with sodium carbonate, sodium sulphate, and sodium chloride, and with the high prices at present obtainable for sodium carbonate, it has paid various companies to operate with the waters of these lakes and separate the salts.

In Curry County, Oregon, there have been discovered considerable deposits of priceite, which is a not entirely pure variety of colmanite. The deposit is known as "The Borax Mine" and is located on the Lone Ranch owned by Moore Bros. It lies along the coast 5½ miles north of Brooking. The country rock containing the borax is entirely serpentine. It is reported that the Pacific Coast Borax Co. controls this deposit.

In Lower California there are known to be extensive borax deposits which are being investigated, but due to the uncertain conditions in Mexico, the developments of these deposits have been materially handicapped.

In the South American fields there are reported new borax deposits found near Iquique, Chile. The average values are from 15 to 60 per cent. of borax.

In the northwestern provinces of Argentine there are extensive borax deposits, from which a limited amount of borate of lime is extracted for export.

SOME OF THE PRINCIPAL SUPPLIES OF BORAX MATERIALS
(In metric tons)

Year.	Chile.	Germany. (*b*)	Italy.			United States. (*c*)	Total. (*d*)
			Borax Refined.	Boric Acid.			
				Crude.	Refined.		
1901	11,457	184	544	2,558	347	6,550	21,640
1902	14,327	196	....	2,763	....	15,512	32,798
1903	16,879	159	....	2,583	....	31,232	50,853
1904	16,733	135	569	2,624	314	41,407	61,782
1905	19,612	183	(*e*)1,007	2,700	(*e*)749	42,036	66,287
1906	28,996	161	1,062	2,561	562	52,774	86,116
1907	28,374	114	881	2,305	466	47,945	80,085
1908	35,039	128	(*e*)1,024	2,520	(*e*)429	22,680	61,820
1909	32,218	149	(*e*)1,110	2,431	(*e*)578	37,589	74,075
1910	35,192	167	(*e*) 912	2,502	(*e*)695	38,426	77,894
1911	45,558	160	(*e*) 738	2,648	(*e*)444	48,381	97,929
1912	43,356	224	(*e*) 813	2,309	(*e*)760	38,388	85,850
1913	(*a*) 40,000	(*a*) 200	(*e*)1,071	2,410	(*e*)743	52,600	97,024
1914	34,203	....	1,164	2,537	838	50,609	94,187
1915	....	....	829	2,497	1,277	60,785	....

(*a*) Estimated. (*b*) Boracite. (*c*) Crude borax. (*d*) The total falls short of the world's supply, particularly because it fails to include the important production of Turkey. (*e*) Obtained by treating a part of the crude boric acid reported for the same year.

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BROMINE AND IODINE

Bromine

Bromine occurs in nature associated with salt, and is recovered in connection with the salt industry in Michigan (Mount Pleasant, Midland, St. Charles, and Bay City); Ohio (Pomeroy); and West Virginia (Mason, Hartford, and Malden).[1] It is recovered also from brine wells at some of these places.

In the past 2 years the production has increased and the price more than doubled. At the close of 1916 technical bromine was quoted at $1.30 per lb., but declined to $0.90 in the early part of 1917. The increased demand, however, is not so much due to that required in the manufacture of chemicals as to the demand for export to Europe, where it is doubtless used in the manufacture of gas for military purposes.

MARKETED PRODUCTION OF BROMINE IN THE UNITED STATES (*a*)

Year.	Quantity.	Value.	Year.	Quantity.	Value.
	Pounds.			*Pounds.*	
1901	552,043	$154,572	1909	569,725	$57,600
1902	513,893	128,472	1910	245,437	31,684
1903	598,500	167,580	1911	651,541	110,902
1904	897,100	269,130	1912	647,200	145,805
1905	1,192,758	178,914	1913	572,400	115,436
1906	1,283,250	165,204	1914	576,991	203,094
1907	1,379,496	195,281	1915	855,857	856,307
1908	760,023	73,783	1916	688,260	922,225

(*a*) U. S. Geological Survey.

Iodine

No iodine is produced in the United States, although a possible source exists in the seaweed along the coast. Almost the entire world's output comes from Chile, where it is produced under strict regulation as to quantity and price, in connection with the nitrate industry. A full description was given in MINERAL INDUSTRY, **24** (1915).

Early in 1916 it was decided to erect an iodine factory on Nahodka Bay, Vladivostok.[2] The Russian Colonization Department assigned $60,000 for the purpose. The source of the iodine is the seaweed along the coast. It does not grow farther than 50 ft. from the shore line, and it is gathered by means of hooks from small boats, of which 800 have

[1] *Min. Res.* of *U. S.*, Part II (1915).
[2] *Comm. Rept.*, July 18, 1916.

been ordered. It was intended to gather and work at least 8000 long tons of seaweed during the summer of 1916.

There was an exceptionally strong demand for iodine in the United States. The imports reached the figure of 2,033,068 lb., of which only 3622 lb. was re-exported. On account of the foreign regulation, which has always maintained a high price, the advance was not proportionately great. $4.25 per lb. was quoted in *Metallurgical and Chemical Engineering* at the end of 1916, but this declined to $3.50 early in 1917.

The imports of iodine into the United States are given in the following table:

Year.	Crude and Resublimed.	
	Pounds.	Value.
1910	771,090	$1,051,060
1911	423,408	841,740
1912	379,311	737,109
1913	240,045	525,959
1914	463,333	951,308
1915	612,926	1,332,387
1916	2,033,068	5,158,265

CADMIUM

By Allison Butts

Germany has been the chief producer of cadmium in past years. The metal was first produced in the United States in 1906 by the Grasselli Chemical Co. Since then domestic production has increased until at present it exceeds the demand for home consumption. The imports have decreased correspondingly from a value of $10,552 in 1906. The following table shows the imports for the fiscal year ending June 30:

	Pounds.	Value.
1910	3,083	1,657
1911	5,956	3,718
1912	6,396	4,603
1913	1,999	1,508
1914	1,543	1,239
1915	264	278
1916	5	6

The production in Upper Silesia, the cadmium district of Germany, is shown in the following table:[1]

Year.	Kilograms.	Value, Marks.
1909	37,187	198,288
1910	41,057	165,166
1911	42,575	224,254
1912	42,757	267,399
1913	38,575	233,812

According to Messrs. Speier of Breslau the production in Upper Silesia was 8815 kg. for the first quarter of 1914.

There are now several producers in the United States, but the bulk of the production is by three companies: the Grasselli Chemical Co., the American Smelting and Refining Co., and the United States Smelting Co. Most of the American production is obtained by treatment of bag-house fumes from lead smelters and is marketed in the form of sticks of refined metal. Some is obtained in different ways in the treatment of zinc-bearing material, and some is marketed as the sulphide known as "cadmium yellow." A large proportion of the foreign production is in this form, and in Germany it is obtained almost wholly as a by-product in zinc smelting by fractional distillation.

[1] *Metall und Erz*, **12**, 235 (1915).

PRODUCTION OF CADMIUM IN THE UNITED STATES (a)

Year.	Metal, Lb.	Value.	Sulphide, Lb.	Value	Total Cadmium Content, Lb.	Total Value
1911	26,152	$17,566	2,392	$1,674	28,012	$19,240
1912	52,508	39,875	8,998	6,400	59,504	46,275
1913	54,198	41,838	17,302	12,136	67,650	53,974
1914	91,409	81,205	22,723	20,241	109,076	101,446
1915	91,415	108,443	10,624	12,057	99,675	120,500
1916	....	....	....	....	....	....

(a) U. S. Geological Survey.

The demand has been nearly stationary during 1916. The price dropped in the first part of the year from $1.75 to $1.90 per lb. to $1.30 to $1.50, and then remained at the latter figure.[1] These quotations are for stick metal in quantity.

A process developed by R. H. Stevens for recovering cadmium and other metals from bag-house dust has been assigned to the United States Smelting Co.[2] The material is first dead-roasted, converting all cadmium to the oxide. It is then pulverized and leached with sulphuric acid. Copper, bismuth, etc., dissolved in this solution are first removed by electrolysis and the solution is then electrolyzed for cadmium at a voltage of from 2.2 to 3.4, and a current density of from 1.5 to 7.5 amp. per sq. ft. The deposit is usually non-coherent and the tanks are provided with false bottoms for its removal. The deposit is melted under a cover of fused sodium hydroxide to remove arsenic and tellurium, cast into anode plates, and refined electrolytically. The electrolyte is a solution of cadmium sulphate, sulphuric acid, and a salt of sulphocyanic acid which prevents deposition of copper. The voltage is about 0.4 and the current density about 5 amp. per sq. ft. A coherent deposit is obtained by agitation of the electrolyte. The solution tends to build up in cadmium, requiring the use of insoluble anodes. These are arranged one in each regular tank and connected to an independent circuit of which the current is so regulated as to maintain the proper acidity.

A translation by Oliver C. Ralston[3] of an article by Franz Juretzka in *Metall und Erz* discusses the European metallurgy of cadmium in some detail.

There has been considerable discussion in the technical press of the effect of cadmium as impurity in spelter. W. R. Ingalls read a paper on this subject before the Institute of Metals. He states that to his knowledge the injurious effect of cadmium in spelter has been definitely established only in the case of sheet-rolling, wire-galvanizing, and the making of certain ornamental castings.

[1] *Eng. Min. Jour.*
[2] *Min. Eng. World*, **45**, 661.
[3] *Met. Chem. Eng.*, **16**, 146.

CEMENT

By Robert W. Lesley

The year 1916 was a normal one in the cement industry from an economic standpoint inasmuch as it was marked by increased shipments, decreased stocks and a constant advance in price. This increase, which showed itself in the western section of the country in the latter part of the year 1915 was manifest over all sections of the United States during the year 1916. The average factory price in bulk at the mills was $1.058 per bbl. compared with $0.860 in 1915, an increase of $0.198 or 23 per cent. While shipments increased from 86,891,681 bbl. to 94,552,296 bbl., an increase of nearly 9 per cent., stock of cement on hand fell from 11,462,523 bbl. in 1915 to 8,360,478 in 1916, a decrease of 27.1 per cent.

During the year the prices of building materials—stone, brick, lumber, steel, hardware, slate, lime and sand—all showed marked increases in price due to advances in the cost of coal, labor and other materials required for their production. Several times during the year 1916, comparisons made in trade papers as to the advances in the various materials of construction showed as a broad proposition that Portland cement had advanced less than other building materials.

Interesting facts in connection with the year's business are to be discovered in the figures of consumption of Portland cement by States and groups of States according to our well-known division into the Eastern, Middle and Southern, Mid-Western States, etc. While in 1913, 37.55 per cent. of the total consumption of Portland cement in the United States was consumed in the States of Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, Connecticut, New York, New Jersey, Pennsylvania, Delaware, Maryland, Virginia, West Virginia and the District of Columbia, and the Mid-Western States of Ohio, Indiana, Michigan, Illinois, Wisconsin, Minnesota and Iowa consumed in the same year 33.34 per cent., in 1916 these figures were practically reversed, the Eastern States consuming only 33.69 per cent. while the Mid-Western States consumed 37.61 per cent. of the whole.

Taking the same 2 years as standards, the Southern States practically made no change in the percentage of cement used while the Western States of North and South Dakota, Nebraska, Kansas, Missouri, Arkansas, Texas, Oklahoma and Colorado increased their consumption from 10.5 per cent. of the whole in 1913 to 12.83 per cent. in 1916. The Far-Western States, on the other hand, showed a decrease from 12.53 per cent. in 1913 to 9.36 per cent. in 1916.

With these figures, which indicate that a greater bulk of cement is consumed in the Mid-Western States and that the percentage of consumption along the Atlantic Coast States is diminishing, it is not difficult to realize why it is that the percentage of Portland cement produced in the old and well-established Lehigh district—practically the first great producer in the country—has been slowly falling back so that its percentage of production to the whole amount of cement produced in the country has fallen away from a maximum of 74.8 per cent. in 1897 to a fraction over 24 per cent. in 1916.

While new cement works have not been built in any great number during the year 1916, the purchase of cement plants by large companies to increase their facilities for geographical distribution has been made in several cases and by this means the distribution of a single brand of cement over practically a national field is accomplished at the lowest price for production and lowest cost for freight distribution against the ultimate consumer. This plan of geographical distribution of cement mills under a single organization and with a single brand is likely to be more followed in the industry and to be productive of valuable results.

From the report of the Geological Survey, Table I given below shows the cement marketed in the United States in 1914–1915–1916.

TABLE I.—PRODUCTION OF MARKETED CEMENT IN THE U. S. IN 1914–1916, BY CLASSES

Class.	1914.		1915.		1916.	
	Quantity (Barrels).	Value.	Quantity (Barrels).	Value.	Quantity (Barrels).	Value.
Portland	86,437,956	$80,118,475	86,891,681	$74,726,846	94,552,296	$100,014,882
Natural	751,285	351,370	750,863	358,627	842,137	430,874
Puzzolan	68,311	63,358	42,678	39,801		
Total	87,257,552	$80,533,203	87,685,222	$75,125,274	95,394,433	$100,445,736

Table II shows the distribution of the cement mills into the various districts, the production and shipments in barrels and the average factory price per barrel in 1915 and 1916, together with the relative percentages of change.

TABLE II.—PORTLAND CEMENT, 1915–1916

District.	Production and Shipments (Barrels).			Average Factory Price per Barrel.		
	1915.	1916.	Percentage of Change.	1915.	1916.	Percentage of Change.
Lehigh district (eastern Pennsylvania and western New Jersey):						
Shipments	24,598,950	25,360,287	+ 3.1	$0.699	$0.905	+29.47
Production	24,876,442	24,105,381	− 3.1			
Stock	3,400,936	2,156,825	−36.6			
New York State:						
Shipments	5,275,101	5,603,477	+ 6.2	0.766	1.027	+34.07
Production	5,043,889	5,643,677	+11.9			
Stock	729,436	787,532	+ 8.0			
Ohio and western Pennsylvania:						
Shipments	7,528,383	8,123,492	+ 7.9	0.855	1.026	+20.00
Production	7,300,498	7,936,731	+ 8.7			
Stock	763,112	574,550	−24.7			
Michigan and northeastern Indiana:						
Shipments	5,480,428	5,747,113	+ 4.9	0.944	1.168	+23.73
Production	5,485,951	5,521,876	+ 0.7			
Stock	677,608	451,724	−33.3			
Southern Indiana and Kentucky:						
Shipments	2,762,941	3,266,215	+18.2	0.703	0.831	+18.78
Production	2,828,561	3,238,942	+14.5			
Stock	501,432	477,232	− 4.8			
Illinois and northwestern Indiana:						
Shipments	10,879,655	10,637,659	− 2.2	0.907	1.056	+16.43
Production	10,242,869	10,360,563	+ 1.1			
Stock	1,479,474	1,193,341	−19.3			
Maryland, Virginia, and West Virginia:						
Shipments	3,166,721	3,315,323	+ 4.7	0.816	0.904	+10.78
Production	3,193,805	3,189,585	− 0.1			
Stock	359,913	235,511	−34.6			
Tennessee, Alabama, and Georgia:						
Shipments	3,099,770	3,541,572	+14.3	0.756	0.980	+29.63
Production	3,010,037	3,502,259	+16.4			
Stock	279,445	237,395	−15.0			
Iowa, Missouri, and Minnesota: (*a*)						
Shipments	9,218,820	11,178,790	+21.3	0.882	1.089	+23.47
Production	9,186,401	10,592,234	+15.3			
Stock	1,440,304	852,549	−40.8			
Nebraska, Kansas, Oklahoma, and central Texas: (*b*)						
Shipments	6,517,258	7,735,418	+18.7	0.872	1.168	+33.95
Production	6,274,863	7,502,111	+19.6			
Stock	632,245	380,695	−39.8			
Rocky Mountain States (Colorado, Utah, Montana, and western Texas):						
Shipments	2,453,095	3,141,855	+28.1	1.289	1.527	+18.46
Production	2,472,069	3,097,385	+25.3			
Stock	242,024	198,984	−17.8			
Pacific coast States (California, Washington and Oregon): (*c*)						
Shipments	5,910,559	6,901,095	+16.8	1.375	1.429	+ 3.93
Production	5,999,522	6,830,454	+13.8			
Stock	956,594	814,140	−14.9			
Total:						
Shipments	86,891,681	94,552,296	+ 8.8	0.860	1.058	+23.02
Production	85,914,907	91,521,198	+ 6.5			
Stock	11,462,523	8,360,478	−27.1			

(*a*) Minnesota, no output in 1915. (*b*) Nebraska, no output in 1916.
(*c*) Oregon, no output in 1915.

The production of Portland cement by States will be seen in Table III, together with the number of plants producing and the percentage of change.

TABLE III.—PRODUCTION OF PORTLAND CEMENT BY STATES

State.	1914.		1915.		Percentage of Change, 1915.
	Producing Plants.	Quantity (Barrels).	Producing Plants.	Quantity (Barrels).	
Pennsylvania	20	26,570,151	20	28,648,941	+ 7.8
Indiana	5	9,595,923	5	8,145,401	−15.1
New York	8	5,886,124	7	5,043,889	−14.3
Illinois	5	5,401,605	4	5,156,869	− 4.5
California	7	5,075,114	7	4,503,306	−11.3
Missouri	5	4,723,906	5	4,626,771	− 2.1
Michigan	11	4,285,345	11	4,765,294	+11.2
Iowa	3	4,233,707	3	4,559,630	+ 7.7
New Jersey	3	3,674,800	3	1,579,173	−57.0
Kansas	9	3,431,142	9	3,580,287	+ 4.3
Texas	4	2,100,341	4	1,939,363	− 7.7
Washington	5	2,017,344	5	1,496,216	−25.8
Ohio	5	1,962,047	5	1,948,826	− 0.7
Utah	3	981,100	3	625,577	−36.2
Other States *a*	17	8,291,521	16	9,295,364	+12.1
Total	110	88,230,170	106	85,914,907	−2.6

a Alabama, Arizona, Colorado, Georgia, Kentucky, Maryland, Montana, Nebraska, Oklahoma, Tennessee, Virginia, and West Virginia; Arizona made no output in 1915.

In Table IV will be found the shipments of Portland cement by states, together with the average price per barrel, as well as the total values.

TABLE IV.—SHIPMENTS OF PORTLAND CEMENT BY STATES

State.	1914.				1915.			
	Shipping Plants.	Quantity (Barrels).	Value.	Average Price per Barrel.	Shipping Plants.	Quantity (Barrels).	Value.	Average Price per Barrel.
Pennsylvania	20	25,985,106	$20,944,787	$0.806	20	28,188,450	$20,252,961	$0.718
Indiana	5	9,540,288	8,342,164	0.874	5	8,577,513	7,336,821	0.855
New York	8	5,474,191	5,020,720	0.917	8	5,275,101	4,039,215	0.766
Illinois	5	5,284,022	4,848,522	0.918	5	5,435,655	4,884,026	0.899
California	7	5,004,633	6,698,905	1.339	7	4,532,452	6,338,918	1.399
Missouri	5	4,706,389	4,485,744	0.953	5	4,628,484	4,007,679	0.866
Iowa	3	4,224,076	4,008,915	0.949	3	4,590,336	4,119,952	0.898
Michigan	11	4,218,429	4,064,781	0.964	11	4,727,768	4,454,608	0.942
New Jersey	3	3,530,476	3,081,205	0.873	3	1,977,474	1,473,499	0.745
Kansas	10	3,237,906	2,643,415	0.816	9	3,780,735	2,826,443	0.748
Texas	4	2,096,140	2,686,653	1.282	4	1,932,828	2,518,233	1.303
Washington	5	2,045,465	2,303,433	1.126	5	1,378,107	1,790,499	1.299
Ohio	5	1,919,859	1,913,797	0.997	5	1,961,409	1,917,920	0.978
Utah	3	974,723	1,317,575	1.352	3	655,116	823,995	1.260
Other States (*a*)	17	8,196,253	7,757,859	0.947	16	9,250,253	7,971,905	0.862
Total	111	86,437,956	$80,118,475	$0.927	109	86,891,681	$74,756,674	$0.860

(*a*) Alabama, Arizona, Colorado, Georgia, Kentucky, Maryland, Montana, Nebraska, Oklahoma, Tennessee, Virginia, and West Virginia; Arizona made no output in 1915.

In examining this last table it will be noted that the increase in price for 1916 over 1915 was not uniform in all the districts, some of them increasing as the Lehigh district did practically 20 cts. per bbl.—a figure almost equal to the average increase all over the country—while in other districts the increase was much less and in one or two cases materially greater. Some of these differences may be accounted for by the fact that the beginning of the increased demand for cement in the year 1916 was marked first in the Far-Western territory and subsequently in the Mid-Western section. In both of these sections natural advances due to exhausted stocks and increased cost of production and the increased demand felt toward the end of 1915 were made and consequently, during 1916, except in a few limited sections of the country, the increase was not as great as in the Lehigh and Western districts, which felt the increased demand at a later period than it was felt in the other territories in the United States.

The average price per barrel from 1870 to 1916 is shown in Table V given below.

TABLE V.—AVERAGE PRICE PER BARREL OF PORTLAND CEMENT, 1870–1916

1870–1880	$3.00	1894	$1.73	1905	$0.94
1881	2.50	1895	1.60	1906	1.13
1882	2.01	1896	1.57	1907	1.11
1883	2.15	1897	1.61	1908	0.85
1884	2.10	1898	1.62	1909	0.813
1885–1888	1.95	1899	1.43	1910	0.891
1889	1.67	1900	1.09	1911	0.844
1890	2.09	1901	0.99	1912	0.813
1891	2.13	1902	1.21	1913	1.005
1892	2.11	1903	1.24	1914	0.927
1893	1.91	1904	0.88	1915	0.860
				1916	1.058

Table VI deals with fuel used in burning cement.

TABLE VI.—STATISTICS SHOWING FUEL USED IN BURNING PORTLAND CEMENT

Fuel.	1914.				1915.			
	Number of Plants.	Number of Kilns.	Barrels.	Percentage of Total.	Number of Plants.	Number of Kilns.	Barrels.	Percentage of Total.
Coal	88	669	72,471,772	82.1	84	597	70,440,529	82.0
Coal and oil	1	24	4,183,842	4.7	1	24	5,124,074	6.0
Coal, oil, and gas	1	5	712,314	0.8	1	5	729,797	0.8
Coal and gas	2	14	1,564,113	1.8	1	7	830,988	1.0
Oil	14	107	7,698,720	8.7	15	105	7,581,467	8.8
Oil and gas	2	15	1,292,578	1.5	1	5	469,762	0.5
Producer gas	1	1	65,420	0.1	1	1	72,777	0.1
Natural gas	1	4	241,411	0.3	2	10	665,513	0.8
Total	110	839	88,230,170	100.0	106	754	85,914,908	100.0

The various materials used in producing Portland cement and the percentage used according to the total production in barrels is shown in Table VII.

TABLE VII.—PRODUCTION, IN BARRELS, AND PERCENTAGE OF TOTAL OUTPUT OF PORTLAND CEMENT IN THE U. S. ACCORDING TO TYPE OF MATERIAL USED, 1898–1914

Year.	Type 1. Cement Rock and Pure Limestone.		Type 2. Limestone and Clay or Shale.		Type 3. Marl and Clay.		Type 4. Blast-furnace Slag and Limestone.	
	Quantity.	Percentage.	Quantity.	Percentage.	Quantity.	Percentage.	Quantity.	Percentage.
1899	4,010,132	70.9	546,200	9.7	1,095,934	19.4	....	....
1900	5,960,739	70.3	1,034,041	12.2	1,454,797	17.1	32,443	0.4
1901	8,503,500	66.9	2,042,209	16.1	2,001,200	15.7	164,316	1.3
1902	10,953,178	63.6	3,738,303	21.7	2,220,453	12.9	318,710	1.8
1903	12,493,694	55.9	6,333,403	28.3	3,052,946	13.7	462,930	2.1
1904	15,173,391	57.2	7,526,323	28.4	3,332,873	12.6	473,294	1.8
1905	18,454,902	52.4	11,172,389	31.7	3,884,178	11.0	1;735,343	4.9
1906	23,896,951	51.4	16,532,212	35.6	3,958,201	8.5	2,076,000	4.5
1907	25,859,095	53.0	17,190,697	35.2	3,606,598	7.4	2,129,000	4.4
1908	20,678,693	40.6	23,047,707	45.0	2,811,212	5.5	4,535,300	8.9
1909	24,274,047	37.3	32,219,365	49.6	2,711,219	4.2	5,786,800	8.9
1910	26,520,911	34.6	39,720,320	51.9	3,307,220	4.3	7,001,500	9.2
1911	26,812,129	34.1	40,665,332	51.8	3,314,176	4.2	7,737,000	9.9
1912	24,712,780	30.0	44,607,776	54.1	2,467,368	3.0	10,650,172	12.9
1913	29,333,490	31.8	47,831,863	51.9	3,734,778	4.1	11,197,800	12.2
1914	24,907,047	28.2	50,168,813	56.9	4,038,310	4.6	9,116,000	10.3

Imports of foreign Portland cement and exports of American Portland cement are shown in Tables VIII and IX.

TABLE VIII.—IMPORTS OF FOREIGN CEMENT, IN BARRELS OF 380 LB.

1881	221,000	1893	2,674,149	1905	896,845
1882	370,406	1894	2,638,107	1906	2,273,493
1883	456,418	1895	2,997,395	1907	2,033,438
1884	585,768	1896	2,989,597	1908	842,121
1885	554,396	1897	2,090,924	1909	443,888
1886	915,255	1898	1,152,861	1910	306,863
1887	1,514,095	1899	2,108,388	1911	164,670
1888	1,835,504	1900	2,386,683	1912	68,503
1889	1,740,356	1901	939,330	1913	84,630
1890	1,940,186	1902	1,963,023	1914	121,863
1891	2,988,313	1903	2,251,969	1915	42,208
1892	2,440,654	1904	968,409	1916	1,804

TABLE IX.—EXPORTS OF CEMENT, IN BARRELS

Year.	Quantity.	Value.	Percentage of Total.	Year.	Quantity.	Value.	Percentage of Total.
1901	373,934	$679,296	1.9	1909	1,056,922	$1,417,534	1.6
1902	340,821	526,471	1.3	1910	2,475,957	3,477,981	3.2
1903	285,463	433,984	0.95	1911	3,135,409	4,632,215	3.9
1904	774,940	1,104,086	2.4	1912	4,215,532	6,160,341	5.1
1905	897,686	1,387,906	2.2	1913	2,964,358	4,270,666	3.2
1906	583,299	944,886	1.1	1914	2,140,197	3,088,809	2.4
1907	900,550	1,450,841	1.7	1915	2,565,031	3,361,451	3.0
1908	846,528	1,249,229	1.6	1916	2,563,976	3,828,231	2.7

So far as imports are concerned, this may be stated to be a closed issue. As the few thousand barrels of foreign Portland cement coming to this country are limited in amount and are practically sporadic shipments, it may be broadly stated that as an importer of foreign Portland cement the United States has ceased to hold place.

In the matter of exports, the figures given show a high point of over 4,000,000 bbl. during the construction of the Panama Canal, but the exports for the last 3 years—1914, 1915, 1916—may be taken to show the growth of the trade, which, while a heavy one, has not yet attained the great magnitude predicted for it some years ago. This hope for increases in export business in the countries of South America has not materialized because of the great European war and the scarcity of ship room to carry the material to destination, and further on account of the lack of capital in the South American countries to carry out many of their important public works and other large construction.

The development of the American Portland cement industry in the lands to the south of us may within the next few years find material competition from the new works now under construction in Cuba and in Argentina under American management and with American machinery. These, together with the reported discovery of coal in Argentina and in Peru, may be productive of material cement developments in the countries named.

Two important developments in the field of manufacturing bid fair to benefit largely the American industry. The first of these is the saving of the dust which has been going up the kiln stacks and the recovery therefrom of potash available for crops and chemical use. The other is a more scientific and successful use of the kiln gases under boilers for the purpose of steam production.

The production of potash from cement dust began at the Riverside works on the Pacific Coast and has been introduced at Security, Md., at Catskill, N. Y., and is under consideration at a number of other plants. At prevailing prices for potash of $400 to $500 a ton, large profits have been made in this field.

On the other hand, under the modern methods of waste-heat utilization under boilers, it has been found that a material decrease in the amount of fuel required to burn a barrel of cement can be made and an increase in general efficiency of heat absorption from 37.6 to 67.2 per cent. of total heat supplied to kilns, the gain being shown in the boiler horsepower developed without any increase in fuel consumed in kiln per barrel of cement produced.

From these two methods much is hoped for to counteract the constantly growing cost of cement caused by high prices for labor and coal.

New uses for cement are constantly being discovered and recommended by the Portland Cement Association, which, with its technical laboratory and large force of experts, has done so much to increase the use of the concrete road. The fireproof schoolhouse, the fireproof "movie" theatre, the fire-proof factory building have all been planned and improved and these with the use of cement in the silo and barn construction have had much to do with the increase in shipments shown for the year.

In the scientific field, the report of the Joint Committee on Concrete and Reinforced Concrete was presented to the various constituent societies—the American Society of Civil Engineers, the Railway Maintenance & Ways Association, the Portland Cement Association, the American Society for Testing Materials, etc.—and has now become the guide to standard practice for engineers and contractors, forming the basis of concrete specification in many of the cities throughout the country.

The new specifications for Portland cement which have been under discussion for several years were also brought to completion during the year 1916 and having the approval and concurrence of the Government have been sent out broadcast and are now the standards for the material in all its uses.

The World's Markets

Canada.—The effect of the war upon the Canadian cement industry has been marked. From an output of 8,886,333 bbl. in 1913, there has been a drop to 4,753,034 bbl. in 1916, or nearly 50 per cent. decrease, due to suspension of public work and the general uncertain conditions prevalent in war times. The average price per barrel at the works in 1916 was $1.218 as compared with $1.228 in 1915, $1.28 in 1914, $1.27 in 1913 and $1.28 in 1912. The Canadian barrel is reckoned, however, upon a basis of 350 lb. as compared with 376 lb. in this country. The tables on production and sales and consumption of Portland cement follow:

PRODUCTION AND SALES OF PORTLAND CEMENT

	1913.	1914.	1915.	1916.
	Bbl.	Bbl.	Bbl.	Bbl.
Portland cement sold or used	8,658,805	7,172,480	5,681,032	5,359,050
Portland cement manufactured	8,886,333	8,727,269	5,153,763	4,753,034
Stock on hand Jan. 1	862,067	1,073,328	2,620,022	2,061,756
Stock on hand Dec. 31	1,089,595	2,628,117	2,062,961	1,444,876
Value of cement sold or used	$11,019,418	$9,187,924	$6,977,024	$6,529,861
Wages paid	$ 3,466,451	$2,271,006	$1,180,882	$1,307,222
Men employed	4,276	2,977	1,679	1,696

CONSUMPTION OF PORTLAND CEMENT

Calendar Year.	Canadian.		Imported.		Total.
	Barrels.	Per Cent.	Barrels.	Per Cent.	Barrels.
1912	7,132,732	83.3	1,434,413	16.7	8,567,145
1913	8,658,805	97.1	254,093	2.9	8,912,988
1914	7,172,480	98.7	98,022	1.3	7,270,502
1915	5,681,032	99.5	28,190	0.5	5,709,222
1916	5,359,050	99.6	20,595	0.4	5,379,645

Germany.—But little is known of the production of German Portland cement during the year 1916. The war conditions have largely stopped construction, but large quantities of cement have been used in the trenches. The Silesian Portland Cement Co. has advanced its prices and attempts have been made to make Cartell agreements with the Rhenish-Westphalian and Central Groups of German manufacturers.

Austria.—The Austrian cement industry has been paralyzed by the war. None of the big companies paid any dividends last year and the output was less than 45 per cent. of the normal.

Spain.—Spain has now nine plants devoted to the making of Portland cement, five of which are comparatively modern. The present production is about 350,000 tons per annum, which it is expected will be increased to 500,000 tons, more than the annual requirements of the country, which aggregated some 450,000 tons. As a result of the increased output of the Spanish works, exports of cement in 1916 grew from 11,308 to 16,422 tons. Spain is also a large producer of natural cement, there being some 61 plants producing this character of material.

Brazil.—There has been a considerable decrease in the imports of Portland cement into Brazil, the figures being as follows:

Total value of imports decreased from $7,119,210 in 1913 to $2,504,061 in 1914 and $2,611,315 in 1915.

Guatemala.—A cement mill with a capacity of from 50,000 to 100,000 bbl. of Portland cement has been recently completed by American interests, located about 1 mile from Guatemala City. The plant has been under construction for 2 years and is operating under a special concession of the Guatemala Government.

Cuba.—Rapid progress is being made with the construction by American capital of the new cement works near Havana. Boston banking interests are back of the enterprise and American machinery will be employed and American engineers are constructing the works.

Argentina.—The new factory at Sierra Bayas, which is being financed by the same group of capitalists who are interested in the Cuban cement works above described, is now under way, and machinery for the factory has already been ordered and the structure is to be erected under the supervision of cement experts who have come from the United States. The new plant is to produce at the rate of 1,000,000 bbl. per annum and will be operating in 1918.

Japan.—Hitherto the total output of cement in Japan has been unknown, as the manufacturers kept their actual capacities secret from business motives. Recently a proposal was made that cement manufacturers should take steps to regulate the relation between supply and demand, and on Nov. 15 a special meeting of manufacturers from all over the country was held in Osaka. As a first step to consider the proposal, the Japan *Chronicle* reports, the meeting investigated the total output of cement in Japan during the past 7 years, with other particulars. The result is shown in the following table:

Years.	Output (Barrels).	Domestic Sale (Barrels).	Export (Barrels).
1909	2,540,000	1,986,000	149,000
1910	2,639,000	2,520,000	231,000
1911	3,192,000	3,302,000	67,000
1912	3,803,000	3,256,000	48,000
1913	3,741,000	3,528,000	148,000
1914	3,625,000	3,611,000	249,000
1915	3,943,000	3,273,000	668,000

"It will be seen," says *Commerce Reports*, "that in 1915 the output and the demand for cement were almost equal. From this year onward there will be a growing increase in output, while the future prospects of the export trade in this line are not very encouraging. It is estimated that, as compared with 1915, the output this year will show an increase of 522,000 bbl. and next year of 3,235,000, while the increase for 1918 will amount to no less than 7,691,000 bbl. Indeed cement manufacturers have a very difficult problem to tackle with such an enormous increase in output, especially after the war."

There are about 16 cement companies in Japan and 20 factories, and the present price is about double that ruling at the beginning of the year, all due to increased export markets and increased domestic demand.

China.—More cement was produced last year than ever before, 66,979 metric tons, as compared with 51,435 tons in 1914 and 50,117 tons in 1913. The Tonkin cement is all produced by La Societe des Ciments Portland Artificiels de l'Indochine at Haifong. About 74,075 tons of cement stone was exported to the Green Island factory near Hong-kong in 1915, against 120,500 tons in 1914 and 95,850 tons in 1913.

South Africa.—There are only two large cement works in the Union—the Pretoria Portland Cement Co., and the Whites South African Cement Co., which is operating on the Vaal River.

CHROMIUM

By Samuel H. Dolbear

Chromic iron ore is the chief source of chromium. It occurs associated with basic rocks, and is usually found in serpentine areas. The ore is essentially a segregation of magmatic solutions, which accounts for the irregular shapes of the ore-bodies. These are characteristically elongated lenses, the boundaries of which are not usually well defined, the ore becoming gradually diluted by the enclosing serpentines.

Theoretically, pure chrome ore contains about 68 per cent. chromium sesquioxide, and 32 per cent. iron protoxide. Alumina, magnesia, and silica are commonly present, replacing the other impurities.

Production and Imports

Year.	Quantity, (Long Tons).	Value.
1900	140	$1,400
1901	368	5,790
1902	315	4,567
1903	150	2,250
1904	123	1,845
1905	22	375
1906	107	1,800
1907	290	5,640
1908	359	7,230
1909	598	8,300
1910	205	2,729
1911	120	1,629
1912	201	2,753
1913	255	2,854
1914	591	8,715
1915	3,281	36,744
1916	40,000	640,000

The production of chrome ore in 1916 in the United States is estimated by the U. S. Geological Survey at 40,000 long tons. This is by far the greatest production ever made in this country, and is over twelve times that of the previous year. Imports for the same period were 114,665 long tons, as compared with 76,455 long tons in 1915.

Embargoes[1] were placed on the shipments of chrome ore from some of the principal sources, and it was feared by some that the supply for the United States would be cut off; but after the producers received a guaranty that the ore would not be re-shipped to enemy belligerents the imports, as shown in the following table, greatly increased, especially those from Rhodesia, New Caledonia, and Canada, though those from Greece have declined slightly and those from Turkey have entirely ceased.

[1] J. S. Diller, U .S. Geol. Surv. *Bull.* 666-A.

CHROMIC IRON IMPORTED INTO THE UNITED STATES, 1913–1916, IN LONG TONS (*a*)

	1913.	1914.	1915.	1916.
Cuba	....	....	....	34
Canada	....	533	10,087	10,930
England	....	58	2	5
Greece	....	8,155	4,305	7,900
Japan	322	....	....	....
French Oceania	6,620	30,860	28,031	(*b*)30,950
Australia	....	....	....	(*b*) 2,968
British South Africa	....	....	22,800	(*c*)23,000
Portuguese Africa	29,000	23,200	11,230	(*c*)38,850
Turkey in Asia	13,830	11,880	....	....
Total	49,772	74,686	76,455	114,655

(*a*) Statistics furnished by the Department of Commerce, Bureau of Foreign and Domestic Commerce. (*b*) E. J. Lavino & Co. importers, credit New Caledonia with all that listed above under French Oceania and Australia, amounting to 33,936 long tons. (*c*) E. J. Lavino & Co. importers, credit Rhodesia with all that listed above under British South Africa, amounting to 61,850 long tons (J. S. Diller, U. S. Geol. Surv. *Bull.* 666-A.)

The importations of chrome ore, chromic acid, and chromate of potash are given in the following table:

CHROMATE AND BICHROMATE OF POTASH, CHROMIC ACID, AND CHROME ORE IMPORTED AND ENTERED FOR CONSUMPTION IN THE UNITED STATES (*a*)

Year.	Chromate and Bichromate of Potash.		Chromic Acid.		Chrome Ore.		Total Value.
	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	
	Pounds.		Pounds.		Long Tons.		
1910	406,790	$19,569	9,850	$1,635	38,579	$415,768	$436,972
1911	22,408	2,159	6,789	1,349	37,540	407,958	411,466
1912	32,913	3,085	8,728	1,376	53,929	499,818	504,279
1913	18,629	1,819	5,562	1,100	65,180	622,821	625,740
1914	31,858	2,375	9,164	1,597	74,686	655,306	659,278
1915	32,942	2,902	3,571	755	76,455	780,061	783,718
1916	459	75	*Nil.*	*Nil.*	115,886	1,548,402	1,548,477

(*a*) Bureau of Foreign and Domestic Commerce.

The quantity and value of imports of chrome yellow or green are given in the following table:

Year.	Quantity, Pounds.	Value.
1910	170,073	$23,107
1911	156,586	25,029
1912	156,733	25,516
1913	161,153	24,731
1914	154,933	24,922
1915	48,303	9,492
1916	29,495	6,099

In the United States, California contributed the largest production of chromite, shipments being variously estimated at from 35,000 to 47,000 tons.

Oregon became a producer in 1916 and shipped 3000 tons. This ore was all mined in the southwestern part of the State, the largest producer being the Collard and Moore mine near Kerby, Josephine County. Other shipments were made from the vicinity of Riddle and Grant's Pass.

Development work was carried on at other points in the State, notably along the eastern border, and some ore has been shipped.

Some of the ore in the southwestern part of the State is too low grade to market without refinement, and it is planned to crush and concentrate it. At Kerby an old concentrating plant has been partly rebuilt, but this is not yet in operation.

In California most of the deposits mined have been small, yielding not more than 100 tons or so, although a few have produced as much as 1000 or 1500 tons.

Some shipments have originated in the Coast Range, notably in the San Louis Obispo County fields, but by far the greater number of mines have been found in the Sierra Nevadas, from Tulare County in the south to Plumas County in the north.

In the Klamath Range in northern California has been developed the largest individual producer, situated near Dunsmuir, Cal. This mine is controlled by the California Chrome Co. and is but a short distance from rail. The mine is provided with a tram-line to the railroad and production at times has reached 2 carloads per day.

New discoveries are being constantly made and the demand for chromite at high prices has stimulated prospecting in every field where the ore is likely to occur. The increase in price paid for the ore has made it possible to work new deposits which were heretofore too remote from rail transportation to justify operation. During the coming year it seems probable that concentrating plants will be erected in some of the chrome districts to treat not only the lower-grade ores but also chromite sands which are found in these areas.

Tulare County.—The Vaughn mine, which yielded about 2500 tons, has been exhausted. Occasional cars are shipped from other parts of the county, the ore averaging about 40 per cent. Cr_2O_3 and 6 to 8 per cent. SiO_2.

Fresno County.—The district northeast of Piedra and Clovis has contributed several thousand tons of ore during the past year, the largest yield by far being that of the Clara H. mine and other contiguous claims in that group. A depth of about 100 ft. was reached in this deposit.

Stanislaus County.—A small amount of ore was shipped from deposits near Patterson, but the grade is reported quite low.

Tuolumne County.—Several hundred tons was shipped from Chinese Camp and Jamestown during 1916, most of which was low-grade.

Calaveras County.—About 800 tons was produced from mines near Angels Camp, the ore averaging about 30 per cent. chromic oxide. Ore of this grade is mixed with higher-grade material from other points in order to secure a commercial percentage.

Amador County.—A few carloads have been shipped from the vicinity of Ione.

El Dorado County.—This county yielded a large tonnage during 1916, most of the ore coming from Folsom. The principal producer was originally opened up by Hill and Hobler, who later sold their deposits to the Noble Electric Steel Co.

Nevada County.—The Grass Valley district was productive during the summer months. The period of production is limited by snowfall and winter road conditions.

Butte County.—Two thousand tons or more was shipped from Oroville, the ore averaging more than 40 per cent. chromic oxide. This district is expected to yield more ore in 1917 when the season opens.

Tehama County.—The Eder Creek mine produced several hundred tons of high-grade ore, which was hauled to Red Bluff for shipment. Other deposits were developed in the same district.

Shasta County.—Much prospecting for chrome was done in this county and several new discoveries were reported. Shipments were made from the Dunn mine and one west of Gibson.

Trinity County.—Some development work was done at Harrison Gulch and Weaverville, but the deposits are 50 or more miles from rail and no shipments were made.

Del Norte County.—Transportation problems prevented shipments from this county and the deposits which were developed 30 or 40 years ago remained idle. These were later leased to southern Oregon operators, who hope to make shipments in 1917.

San Louis Obispo County.—This is one of the oldest chrome districts in the State. Prospecting was carried on during the year and some ore was shipped. The construction of a concentrating plant was planned, but its erection has not yet commenced.

Other States.—Washington, Maryland and Wyoming each produced a little ore in 1916, the aggregate output being given as 800 tons.[1]

Prices

The average price for imported ore was $12.66 per ton abroad. California ore sold from $11 per ton to $20 per ton for ore containing 40 per cent. chromic oxide and not over 8 per cent. silica. A premium of 50 cts. for each unit of 1 per cent. chromic oxide over 40 per cent. is customarily paid and a penalty exacted for ores containing less than 40 per cent. Cr_2O_3 or more than 8 per cent. SiO_2. These prices apply to ore on cars at point of shipment.

[1] U. S. Geological Survey.

Canada

The total shipments of crude chromite ores from Canada in 1916 were 27,030 tons, valued at $229,753. These ores contained a total of approximately 6574 tons of Cr_2O_3 or an average of about 24 per cent. A considerable portion of the low-grade ore and sands, however, amounting to 14,242 tons, was sent to concentrating mills for concentration before being marketed. The quantity thus concentrated was 10,992 tons, from which were recovered 1046 tons of concentrates, averaging from 42 to over 50 per cent. of Cr_2O_3. The final shipments of ore and concentrates approximate 13,834 tons.

The exports of chromite are reported by the Customs Department as 12,633 tons, valued at $152,534.

Production in 1915 was reported as 12,341 tons, valued at $179,540, with exports of 7290 valued at $81,838.

Practically the entire production has been obtained in the district tributary to Thetford and Black Lake, in the eastern townships, Quebec.[1]

THE PRINCIPAL SUPPLIES OF CHROME ORE (*a*)
(In metric tons)

	1906.	1907.	1908.	1909.	1910.	1911.	1912.	1913.	1914.	1915.	1916.
Bosnia	320	310	500	332	320	250	200	305	533	......	......
Canada	7,936	6,528	6,554	2,470	279	143	......	......	123	11,196	24,522
Greece	11,530	11,730	4,350	9,600	9,463	4,615	6,468	6,342	7,059	10,420	......
India	4,445	18,597	4,821	9,398	1,765	3,864	2,936	5,670	5,986	3,828	......
Japan	......	......	......	......	2,091	1,500	......	......	2,108	2,979	......
New Caledonia (*b*)	57,367	25,371	46,890	40,000	40,000	82,806	51,516	63,370	......	......	......
New South Wales	15	30	*Nil.*	*Nil.*	*Nil.*	150	23	*Nil.*	*Nil.*	*Nil.*	......
Rhodesia	3,308	7,273	12,118	37,024	40,000	47,600	62,850	63,384	49,009	61,590	......
Russia	16,969	25,528	10,950	22,213	1,362	1,238	21,277	......	......	......	......
Turkey	......	21,111	28,394	11,364	......	......	......	......	......	......	......
United States	109	294	364	606	208	122	204	259	601	3,336	40,000

(*a*) From the official reports of the respective countries. No complete statistics are available for Turkey or Africa. (*b*) Exports, except 1909 and 1910.

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[1] *Preliminary Report of the Mineral Production of Canada for* 1916, Department of Mines.

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COAL AND COKE

By A. T. Shurick[1]

The United States produced 582 million tons of coal last year, exceeding the previous high record of 1913 by 13 million tons. This represents an increase over last year of 51 million tons, the greatest increase ever made in the modern history of the coal industry with the exception of the year 1907, which made a gain of 66 million tons over the preceding year.

It has been a year of great stress and momentous happenings. A demand of the most urgent character, bordering at times on the hysterical, developed during the last half of the year that whirled spot prices up to levels comparable only with the strike period of 1902. Threatened fuel famines became the rule rather than the exception. Drastic railroad embargoes were put into effect and rigid legal investigations of all descriptions were instituted, while abrogations of contracts were reported on every hand. Never in a period of normal production has there been such a desperate shortage of fuel as marked the concluding months of 1916.

Coal operators increased their earnings substantially, though not to the extent that might be expected. The rapidly advancing prices found a large percentage of the possible production covered by relatively low-priced contracts concluded under the usual conditions of severe competition; instead of being able to participate in the high prices ruling in the prompt market, therefore, producers were exceedingly hard pressed to meet their contract obligations. Arrogant demands for increased wages by the miners, often in direct violation of recent wage agreements, together with the increased cost of supplies of all descriptions, and difficulty and long delays in obtaining them, were further contributing factors on the wrong side.

The constantly increasing strength that characterized the closing period of 1915 carried over into the new year and, for the first time in about 8 years, operators were reasonably sure of a sustained 12 months' period of profitable figures and active operations.

Evidence of the general expansion in business was seen in the uniform increases in the tonnage statements of all descriptions. The anthracite shipments made a gain of 2½ million tons in the first 2 months of the year. Shipments of the Pennsylvania R.R. indicated an increase of

[1] Abstracted from *Coal Age*, Jan. 13, 1917, p. 72.

$3\frac{1}{2}$ million tons for the same period and the Norfolk & Western 2 million tons. Exports were increasing very rapidly and showing a substantial gain in spite of the heavy losses in the movement to Canada, occasioned by the depression incident to the war.

By the time the fall trade began to open it was obvious that the big interests were exerting their best efforts to put the brakes on what threatened to be a runaway market. The mines were beginning to run shorthanded, car supply was inadequate, while big industrial consumers were requiring tonnages in excess of what their contracts called for, thus throwing a very substantial extra demand in the spot market. Coal salesmen were withdrawn almost entirely and the operating interests became very critical on the matter of credits, arbitrarily cutting off shipments to any consumers in arrears.

The one unexpected turn to the situation was the fact that the burden of the high prices was in a number of instances turned back on the wholesale and operating interests. They were under very stiff contract obligations that not only prevented them from participating to any appreciable extent in the high spot prices, but in a number of instances forced them into the market for supplemental tonnages to meet their contracts. It has been well recognized that the conditions of competition have forced prices to the very minimum, and many of the agencies that bid so aggressively for business now realize their mistake.

With consumption at record-breaking proportions in the early fall, the usual increase in domestic buying at this time found supplies scarce, with the result that prices were bid up in an extraordinary manner. A great deal of exaggerated newspaper publicity created a general scare and precipitated buying of the most reckless description. The shortage developed by the big floods in West Virginia during the summer was also a contributing factor.

In the steel industry the mills were operating far in excess of any previous record and fuel requirements were running considerably ahead of contracts. With profits ranging at heretofore unheard-of figures, the steel men were not disposed to take any chances on their fuel supply, which formed a relatively insignificant item in comparison with their returns. As a result inquiries developed from this source, and the matter of prices was a secondary consideration.

Conditions reached the point where some steam consumers were hard-pressed for sufficient supply to keep their plants in operation, the situation becoming acute in the case of a number of public service corporations. As was to be expected, the customary complaints against the coal industry in general began to appear, and investigations were instituted by Federal, State, and municipal authorities in all parts of the country.

These abnormal conditions created an unstable situation in the market, particularly as regards Middle Western coal, which seemed to be meeting the stringency in much better shape than other districts. As a result of this there was a material broadening in the market for these fuels. Shipments were made into Ohio, and even as far east as Buffalo and New York, a most unheard-of market for Illinois coal. Demand for these fuels also began to develop in other directions. A temporary strike of the miners in the Oklahoma coal field created quite a little inquiry, while orders were received from Western points, such as Kansas City. A very urgent demand appeared in the Northwest. Lake shipments in this direction were substantially below requirements and it was clear that consumers in that district would be obliged to rely, to a great extent, on all-rail shipments.

Had it not been for a long period of warm weather that prevailed well into December, it is certain that critical conditions would have developed in the coal supply before the end of the year. As it was, the situation was kept moderately well in hand.

The anthracite industry passed through the most turbulent year in its history. The so-called trusts have been subjected to governmental investigations of every description, while the industry itself has been obviously lacking in the effective coördination that has characterized it in recent years. In fact the past year has witnessed the most amazing indecision and panicky reversal of plans. Time after time we have had pitiful examples of an abject subservience to threatened investigations.

In May the coal-consuming public was treated to the strange spectacle of the anthracite operators haggling among themselves over the question of prices. Following the precedent of other years, it was expected that price schedules would be announced, but when this was delayed beyond May 5, inquiries became urgent. The circulars were apparently on the point of being issued several different times, only to be hurriedly withdrawn at the last moment. Finally, a circular was issued and some business was negotiated. But the following day the Department of Justice in Washington issued a threatening statement announcing its intention to investigate the possibility of collusion in the fixing of coal prices, and the circular was hurriedly withdrawn.

Acting in accord with the general trend of business, the year has witnessed a tremendous boom in the anthracite trade with the demand very active and at top prices. Anticipation of labor troubles at the mines occasioned rather unusually heavy stocking early in the season, though this proved a big advantage even as early as June, when the demand was substantially stronger than in normal seasons. This steadily increased as the season advanced and was due largely to the plethora of money occasioned by the great prosperity of the country. By October there were exceptionally strong demands from the West and New England, where fair premiums were offered by consumers desirous of making sure of their stocks before the bad weather began. The shortage was also being felt in the East by this time, though the big companies continued adhering to their circular prices.

Perhaps the most significant fact in our export business was that it actually showed a very marked falling off. Government figures, of course, indicate an increase of from slightly less than 11 million tons in 1915 to between 15 and 16 million tons for 1916. But by far the larger proportion of our theoretical exports go to Canada, which it does not seem proper to consider as a factor in discussing what is commonly interpreted as the real export business. Disregarding these figures, therefore, the real off-shore exports in 1916 amounted to only about 7¼ million tons as compared with 8½ million in 1915.

With British foreign shipments showing a heavy decline month after month, Germany practically eliminated from the world's coal markets, and our own exports falling off, it is difficult to arrive at a satisfactory explanation of how this deficiency is being made up. The only real explanation seems to lie in a generally reduced consumption in the foreign markets, or possibly in a largely increased export business from the smaller producing countries where no recent statistics are available.

Foreign inquiries involving enormous tonnages were received in this market during the year. It is clear that the shortage of coal in Europe is the most severe in recent times, the situation frequently reaching a point where prices were so prohibitive that only those companies making abnormal profits on war orders were able to meet the high figures. In the more remote markets, as for instance Russia, it was frequently necessary to adopt substitutes such as wood and peat.

Coal Market Conditions

Boston, Mass.[1]—Every coal year has its leaning toward the unusual, but 1916 is clearly entitled to the lead in this respect. Other years had their labor disturbances, their car shortages, their high prices, but never has there been so long a period of sustained irregularity as in the 12 months just ended. The country has enjoyed a year of unparalled prosperity, but the seaboard coal trade as a whole has not profited in anything like the degree that might be looked for.

True, we had record prices, but because of 1916's peculiar inheritance the large factors in bituminous suffered for the sins of 1915, due to the old-

[1] Abstracted from *Coal Age*, Jan. 13, 1917, p. 77.

time grasp for tonnage that is always so hard to control. In January the newspapers were giving publicity to all the serious phases of car, labor and boat shortages; in December they were but striking the same note with more emphasis. Aside from the recessions usual in the spring, after a hard season, the 12 months as a year measured a steady climb in prices, while all the time a large number of hapless contractors were struggling to make good on their old and long-term obligations. That, in a word, is the record of 1916 in the coastwise market.

Manufacturing in New England thrived, fuel demands were greater, and in spite of all the adverse conditions receipts of coal were heavier than ever before. And the remarkable thing is that buyers of every kind are apparently reconciled to higher prices. There is a distinct feeling that coal is only getting its share of the wave of higher return that prevails on most commodities. The anthracite operators, for instance, made their appeal with commendable frankness, and when domestic sizes were scaled up as a result of the wage settlement the public paid the bill, and nothing was said. As long as the buyer could be assured of his special supply, large or small, he was inclined to be grateful, and the record of 1916 was singularly free of that recrimination so familiar in other years.

The flurry of November and December, 1915, gave an impetus that persisted throughout the year. Tidewater receipts continued light through January; the mild weather that intervened only postponed the reckoning. The price paid by the buyer in distress created the "market" for spot coal. Until well into the spring the great anxiety over deliveries completely overshadowed all consideration of season purchase.

Consumers who otherwise would have been forced into the market on the expiration of old contracts were able in some cases to arrange quietly for supplies through the same channels, leaving the price to be adjusted from month to month. Measures like this kept a number of well-connected buyers from open purchases. The lot of the consumer without a 1915-made contract was hard, but even the buyer with contract in hand was not without his full share of anxiety. If his contract did not cover all requirements, or if his contractors were in arrears, he could not be sure which was better—to turn to the railroads for all-rail delivery or to rely upon a sufficient supply of boats to see him through. In neither direction was there much encouragement.

Until the situation cleared, practically all the shippers declined flatly to make prices for extended shipment and, as usual, New England "marked time." The larger volume of choice business had been closed the previous October, but for the others the longer the wait the more complicated the outlook. It was seen that the New England situation would be largely dependent upon water-borne coal, and by May and June the more far-sighted had covered themselves one way or another; the remaining few stayed out to help other unfortunates bid up prices as the season advanced.

It was the sudden revival of commerce that did the mischief. The railroads were unprepared and the shortage of cars mounted to unheard-of proportions. Every effort at remedy proved futile, so far as any significant improvement was concerned. Directions of the Interstate Commerce Commission were followed. But from a sectional standpoint, hardship rather than benefit was the result. New England cars did not figure high enough in percentage as compared with those of other sections, and it was only the more difficult for this territory to get its quota of coal. When all is said, only tremendous increases in equipment and track and other facilities could have given any real relief. That the shortage of cars was not wholly the cause of congestion appeared in frequent cases where trains were stalled for lack of adequate motive power.

Frequent embargoes from January to December brought conditions home to New England and threw a greater dependence upon water coal than has heretofore been the practice. It was soon found that operators, anthracite as well as bituminous, were being obliged to load cars for sections where the need was not so great to the exclusion of other sections where there was genuine distress. The New England railroads themselves anticipated interruptions by establishing new storage depots and simply dumping coal on unoccupied land. In this way only did they assure themselves of a sufficient reserve supply.

The shortage of bottoms was another continuing obstacle to coastwise trade. Only those interests who owned or controlled transportation could make delivered prices for any period, and offshore freighting was so attractive that, speaking broadly, New England was held down to bare contract requirements. In cases like that of the Georges Creek factors, where deliveries were notably in arrears, the deficit usually had to be made up in the open market, partly through the purchase of speculative cargoes. Unfavorable weather through June, July and August only added to the difficulties of transportation.

On top of everything else mines in all the regions were short-handed. New wage scales were agreed upon in the Pennsylvania bituminous districts as well as in the anthracite, supplemented by numerous special and local adjustments. The car situation only aggravated conditions, because mine workers were not inclined to stay unless given the opportunity of continuous work. The year was a hard one in which to keep miners, man-power being short in every industry.

Perhaps the saddest chapter in this record of unusual features is the extent to which the wholesaler bore the brunt of all the shortages. Not only were producers unable to take full advantage of panic prices, but they were under stiff obligation to fill contracts undertaken when tonnage seemed the only objective. The real agony came when the very agencies that moved heaven and earth to secure contracts at any price then obtainable were forced to pay the full current spot market to their less eager competitors in order to meet contract requirements.

The year was one long season of continued anxiety. Strike possibilities in March and April were succeeded by local difficulties and dock troubles, and by the threatened tie-up of the railways in September. Disturbing influences were frequent and exasperating, and it is no wonder that hysterical buying and a runaway market were mildly indulged in during the fall. When ocean liners have to call at three different loading piers to fill their bunkers and big ships wait 8 and 9 days for cargo, it is time to admit the coal market has reached an acute stage. Prices jumped 50 cts. and $1 at a time, but there was an anchor in the shape of long-term contracts. Gradually shippers confined themselves to their obligations and spot sales grew less frequent.

After a brief period of recession in prices, due largely to the mildest November weather in 20 years, the coastwise market regained strength, although perhaps more close-hauled than before. All the interests proceeded very cautiously, but there was no tangible prospect of easier conditions for a long time to come. At the close of the year prices advanced by shorter steps, but the trend was no less firm. Sales were rare, and usually for smaller tonnages, but there was more confidence in current levels than was the case earlier.

The 12 months together formed a unique experience for the coal trade. If relief was in sight the latter part of December, there was no one willing to name the quarter whence it would come.

Philadelphia, Penna.[1]—The year 1916 opened with all producing interests announcing increased circular prices. This increase really represented the amount formerly charged as a special item on account of the Pennsylvania State tax of 2½ per cent. on the price of the coal at the mines, but the companies now stated they would no longer charge their customers with this tax. As there was no chance of receiving a refund, as had formerly been the case, the retail dealers in many sections of the country increased the prices of coal to their customers, the increase amounting to as much as 25 cts. a ton in some sections.

Coal was in strong demand at this time and with the arrival of real cold weather the shippers were swamped with orders. The expiration of the agreement with the miners on Apr. 1 began to loom up as a menace to the trade, and everyone began buying heavily in anticipation

[1] Abstracted from *Coal Age*, Jan. 13, 1917, p. 83.

of trouble at that time. The prices of steam coal also advanced rapidly, often bringing as much as 75 cts. to $1 above circular. Shipments were greatly hampered, too, by a shortage of cars.

Much interest was shown at this time as to the attitude the big companies would take on the subject of contracts, most of which had expired on Dec. 31. Heretofore the custom had been to contract for the entire year from Jan. 1, but with Apr. 1 coming it was felt that a change would be made. The operators finally decided to contract only for the first 3 months of the year.

In February much of the activity of the preceding months vanished, on account of the changeable weather conditions. The dealers took advantage of the situation to replenish their stocks, which had been well-nigh depleted. Premium coal at this time disappeared completely. The trade was anxious also to lay in heavy stocks, on account of the threatened labor trouble at the mines, but many railroad embargoes made this difficult of accomplishment.

March still found the trade waiting for seasonable weather, with most interests reporting good stocks on hand. None of the sizes was in active demand except pea, and most companies found it difficult to keep up with the orders on this size. The buyers were placed in a difficult position, for with the first of April near, no one was certain as to the best course to pursue. If the miners should work, and the customary April or spring discount become effective, then no one wanted to have a stock of high-priced coal on hand. On the other hand, if mining was suspended, then every one needed all the coal possible.

Users of steam coal under contract were also anxious as to what would be their position after Apr. 1. Production fell off heavily, as many of the miners, disturbed by the uncertain conditions and attracted by the high wages offered in munition plants throughout the country, began to leave the mines. Orders finally became so scarce that collieries were compelled to shut down, and what was usually one of the busiest months of the year actually became the dullest. In order to keep their plants going some of the producers began selling their product subject to whatever price might be fixed upon later in the month.

In the meantime the miners and the operators had been in session over a new agreement, and at the beginning of May the conference gave every indication of becoming a deadlock, with the consequence that there was again an extremely heavy demand for coal. But a new agreement was reached suddenly, almost without warning, and cancellations of orders followed quickly. After a long wait a new price circular was finally issued, which as a matter of fact was one of the causes of the general apathy of the trade in buying.

The first summer weather in June found prices being cut right and left, with but small business resulting. The general public seemed to have lost interest in their coal supply. For the time being a large proportion of this trade was lost, and short working time in the region became of common occurrence. In addition the application of the terms of the new working scale caused many disagreements, which resulted in many local strikes. Coal also began to come in at this time rather poorly prepared, seeming to lend credence to the rumor of the change in sizes. Furthermore, the operators had increased the prices of steam coal and the manufacturing interests were somewhat loath to close at the new figures. The contract period was also changed to date 1 year from Apr. 1.

Immediately after the signing of the new working agreement the operators met in conference to decide on a new price circular. While this at first appeared to be merely a matter of routine, it soon developed greater difficulties, if possible, than had the agreement with the miners. There seemed to be an entire lack of a guiding spirit in the deliberations.

Late in the month of May a circular was finally agreed upon, then suddenly the information was spread broadcast that the Government officials at Washington were closely watching the proceedings. The statement was plainly made that they were making an investigation and preparing to take legal action if it could be established that the operators were in collusion in naming prices. This completely upset the plans for a new circular and the one tentatively agreed upon was abandoned in its entirety.

It was then announced that each company would name its own prices regardless of the others. The first company to issue a circular was the Philadelphia & Reading Coal and Iron Co., and when it came out it was found to be practically the same as the one given out originally by the joint conference. The other operating companies, following the precedent of many years, soon followed the Reading's lead and adopted the same selling figures.

With the general price circular out of the way interest next centered on the question of contract prices to take the place of the contracts which expired on Apr. 30. In the meantime shipments had been made to all contract customers subject to whatever prices might be agreed upon later. Toward the end of May the figures were given out.

When the first anthracite tax act of 1913, which imposed a tax of 2½ per cent., went into effect, there was some complaint that the retail prices had been increased. At the next session of the State legislature a commission was created for the purpose of ascertaining if the retail men had taken advantage of the situation and passed the tax on the public.

The commission was to consist of three members, without salary, but $5000 was appropriated for expenses.

The Governor of Pennsylvania appointed this commission on Jan. 1, but as several appointees declined, it was not until July 1 that it got under way with its investigation. In selecting the members the Governor for some reason failed to choose any one who had a particular knowledge of the coal business. The commission at this time showed a disposition to conduct its work with as little expense and energy as possible, and formulated a letter with a long list of questions, which it sent to all the retail coal dealers. Many of the questions were so pointed in their inquiry into the personal affairs of the retail men that it actually seemed to be an invasion of their private rights should they be compelled to answer them.

The dealers almost to a unit declined to reply, although there were a few exceptions, steadily maintaining that they did not increase the price of coal as a result of the tax and actually welcoming an investigation, so that they could place their case fairly before the public.

Hampton Roads, Va.[1]—Exports have been heavy, practically on the same basis as last year, due principally to the withdrawal of British coals from neutral markets on account of restricted output. Foreign business, in common with other trade, fell off toward the latter part of the year, due to car shortage.

A glance at the list of countries to which coal is exported from Hampton Roads will disclose the healthy condition of the trade. There are some 40 different countries comprising the British, French, Dutch and Danish West Indies; Mexico and Central America; the whole of the South American continent, both east and west coasts; the Canary Islands; the Azores; the West Coast of Africa; the Dutch East Indies; Cuba; Canada; the Mediterranean; also an occasional cargo to Scandinavia.

The tonnage shipped to the Canal Zone, for the operation of the canal and the coaling stations at Cristóbal and Balboa, aggregating some 600,000 tons per year, is exclusively American coal and is not subject to foreign competition. There is no doubt that a large portion of the exports of 1915 and 1916 was due to the effect of the war on the coal trade of our competitors, but exporters expect to retain a considerable and increasing share of this trade even when conditions again become normal. The smokeless coals of Hampton Roads are well established in foreign markets; also American banks are opening foreign branches. This fact is particularly important, as American exporters expect their banks to assist them in a large measure in extending long credits, to which certain for-

[1] Abstracted from *Coal Age*, Jan. 20, 1917, p. 139.

eign customers are accustomed and which have been granted by our competitors.

Shipments to Southern ports are principally carried by small schooners, as orders for this market are usually for small lots and this class of vessel is engaged in the Southern trade. Coastwise freights have been fairly constant throughout the year. The difference between the lowest and highest rate was about $1.

Bunker deliveries have been fair for the year. This class of business has been largely augmented by steamers loading here and neutral steamers trading to Great Britain and Europe taking on sufficient coal here to take them across and back to the United States, thereby avoiding replenishing their supplies at the high prices ruling at foreign coaling stations. Prices for bunker coal are now conceded to have been too low for 1916 and better prices will no doubt be secured this year.

The high prices prevailing in the latter part of the year have attracted a number of the high volatile coals to Hampton Roads. There is always a small tonnage of these coals moving both coastwise and foreign, but it is only under unusual conditions, such as a shortage of Pocahontas and New River, that any considerable tonnage is shipped to Tidewater.

Prices were on the basis of $2.75 per gross ton for standard Pocahontas and New River coals up to Sept. 1. Shortly before this time consumers all over the country began stocking up in anticipation of a railway strike. This unusual demand exhausted stocks and about the same time the shortage of cars began to be felt. Since that time the car shortage has steadily become more acute and stocks at Hampton Roads have never been replenished. There has been no lessening of demand and as a consequence prices have advanced. At the close of the year the same coal that was selling for $2.75 up to Sept. 1 was bringing $8.50. Most contracts for this territory run from April to April. Bunker contracts, however, are closed for the calendar year.

The principal Australian lines have now decided to make Hampton Roads a port of call. These steamers will help bunker deliveries considerably, as they are all large ships and take heavy supplies. Work has commenced on the construction of a large briquetting plant to supply the export trade.

All records of the Hampton Roads dumpings were broken during the year 1916, when a total of 16,591,575 tons of coal was dumped. This is an increase of 1,799,095 tons over 1915, when the dumpings amounted to 14,812,480 tons.

Pittsburgh.[1]—The coal industry was slow in yielding to the favorable industrial and financial conditions that obtained in 1916. In the pre-

[1] Abstracted from *Coal Age*, Jan. 13, 1917, p. 98.

ceding year it had done little more than show prospects of improvement. Viewed from the standpoint of market prices, there was a spectacular and altogether unprecedented improvement in the Pittsburgh district coal market, but the improvement was confined almost wholly to the last 3 months of the year; and as the volume of coal available for sale was limited, the advance in price was not reflected in earnings to any extent. Indeed, from that standpoint, the chief thing that occurred in 1916 was the establishment of market values by which profits could be made in 1917.

The chief factor in making market prices for prompt coal during the first half of the year was the labor situation. The year opened with prompt coal at about $1.50 for mine-run per net ton at mine, Pittsburgh district, with occasional offerings at somewhat lower prices. At this range there was a disposition on the part of consumers, during January and February, to stock up against a possible suspension of mining Apr. 1, when the biennial wage scale expired. Apparently, it was the expectation of most consumers that there would be a suspension.

Early in March an agreement was reached, but it was a settlement that did not settle. Perhaps no circumstances could be conceived that would have had a more unfavorable effect upon the market than those created by what was known as the "McAlpin Settlement." In the first place the "settlement" broke the prompt market, as consumers ceased stocking and began to draw upon their reserves. In the second place the terms were so poorly understood that many buyers hesitated about closing coal contracts with the usual proviso for a sliding scale price according to the mining rate, as it was not clear what price they would have to pay. The regular circular price for the 12 months beginning Apr. 1 was $1.50, but that price was generally shaded, frequently by 15 cts. or more.

The average market price of spot coal during the first 2 months of the year was about $1.45, but owing to the conditions indicated the market dropped, the average in April being between $1.15 and $1.20. The year had opened with a number of embargoes and these were gradually limited, until early in April the last two important ones, of the Pennsylvania and the New Haven, were taken off. This action did not help the market, which drifted through April and into May, to advance only by reason of strikes growing out of disputes as to how the McAlpin agreement should be interpreted. A strong coal market was produced, with spot coal bringing from $1.60 to $1.75, but of course few operators were benefited. By July 1 the strikes were settled, and the coal market also settled—to $1.30—scarcely even a fair price and certainly not a profitable one, in view of the greatly increased cost of production.

The Lake trade was extremely unsatisfactory for Pittsburgh district operators. The contracts were placed at relatively low figures, and the labor troubles of late May and early June caused some buyers to cancel their contracts on account of the failure to ship, and to buy in other districts. Throughout the season it was difficult to secure Lake vessels, as there was an unprecedented pressure to move iron ore, and boats were disposed to make the up-trip light in order to save a little time.

As already indicated, spot coal sold at times during the first half of the year, and also in July, at less than the average level at which 12-month contracts were made, although these contracts were at considerably below the circular price. So suddenly did the eventual stiffening of prices occur, that the advance above the circular price fell just at the time when the threat of a general railroad strike on Sept. 4 was removed. At the beginning of October spot coal was bringing $2, and at the end of the month the market was $4 to $4.25 for steam and $4.75 to $5 for gas.

There had been continued heavy demand for coal for export, but the demand did not penetrate to the Pittsburgh district to any extent until August. Then it increased sharply, and to this influence was soon added a car shortage that steadily grew more severe. The car shortage decreased shipments to large consumers, on contract, and the steel mills in particular became eager bidders for spot coal, the price being an altogether secondary consideration, as they were striving for the maximum production of steel that was bringing them profits of $30 to $40 a ton. The top was reached early in November, when there were some sales at $5.50 for steam and $6.25 for gas coal. The steel works require a considerable tonnage of gas coal for their gas producers.

SHIPMENTS OF ANTHRACITE

	1913.	1914.	1915.	1916.
Reading	12,914,887	11,998,779	11,488,444	12,842,731
Lehigh Valley	13,011,370	13,136,759	12,932,526	12,056,078
N. J. Central	9,092,433	8,924,936	8,017,816	7,135,544
Lackawanna	9,903,541	9,912,578	9,579,053	10,638,500
Del. & Hudson	7,094,258	7,313,541	8,016,988	7,095,297
Pennsylvania	6,351,756	6,434,937	6,124,596	5,841,475
Erie	8,192,352	8,268,585	7,874,062	7,718,089
N. Y. Ont. & West	2,509,031	2,352,486	2,088,577	1,945,030
Lehigh & New England	....	....	....	2,653,964
Total	69,069,628	68,342,601	66,122,062	67,926,708
Deduction[1]	....	....	....	550,344
				67,376,364

Pennsylvania Railroad.—The following is a statement of shipments over the Pennsylvania Railroad Co.'s lines east of Pittsburgh and Erie for December and the 12 months of 1915 and 1916, in short tons:

[1] Deduction: Tonnage reported by both C. R. R. of N. J. and L. & N. E. R. R.

	December.		12 Months.	
	1916.	1915.	1916.	1915.
Anthracite	962,106	1,079,076	11,996,964	10,953,209
Bituminous	3,828,420	4,298,382	48,167,136	44,514,366
Coke	1,115,255	1,195,899	14,257,911	12,018,404
Total	5,905,781	6,573,357	74,422,011	67,485,979

Norfolk & Western Ry.—The following is a statement of the tonnage shipped over this road during the past 4 years:

	1913.	1914.	1915.	1916.
Coal,				
Tidewater, foreign	1,542,950	1,904,306	3,862,538	3,307,443
Tidewater, coastwise	3,805,847	3,763,420	3,188,259	3,373,072
Domestic	18,543,672	19,804,243	22,890,141	27,680,401
Coke,				
Tidewater, foreign	31,082	1,415	42,311	48,634
Domestic	1,499,302	1,017,196	947,985	1,999,680
Total	25,422,853	26,490,580	30,931,234	36,409,230

Imports and Exports.—The following is a comparative statement of imports and exports of the United States for 1914–15–16, in long tons:

	1914.	1915.	1916.
Imports;			
Anthracite, total	19,347	2,998	5,693
Bituminous, total	1,375,316	1,521,237	1,530,212
United Kingdom	27,421	18,361	5,268
Canada	1,050,592	1,253,829	1,399,570
Japan	75,109	86,919	93,402
Australia	219,941	159,241	30,607
Other countries	2,253	2,887	1,365
Coke	120,777	47,520	49,067
Exports			
Anthracite, total	3,830,244	3,540,506	4,165,679
Canada	3,767,774	3,440,009	4,068,191
Argentina	....	2,526	1,530
Brazil	6	2,415	1,154
Uruguay	....	605	....
Other countries	62,464	94,851	94,804
Bituminous, total	13,801,850	16,764,857	18,977,346
Italy	....	2,931,581	1,735,072
Canada	9,170,901	8,354,365	11,839,384
Panama	267,598	515,341	427,732
Mexico	359,802	279,013	196,547
Cuba	1,074,825	1,165,871	1,284,172
West Indies	552,600	534,925	477,365
Argentina	241,248	786,967	921,969
Brazil	278,026	648,303	782,094
Uruguay	76,088	158,201	152,732
Other countries	1,780,762	1,390,290	1,160,279
Total coal	17,632,094	20,305,263	23,143,025
Coke	592,487	799,562	1,048,790
Bunker coal	7,266,002	7,470,988	7,826,181

Coal Mining in the United States

Alabama.[1]—In the absence of accurate figures, it is believed that a conservative estimate of the coal production in the State of Alabama during the year 1916 would be 16,250,000 short tons and that 4,250,000 short tons of coke was manufactured.

By-product and beehive ovens have been active, owing to the increased demands for iron and steel. The prices for coal have been greatly stimulated recently on account of the increased activities and also because of the shortage of railroad cars. Many abandoned coal mines have been opened for business and in addition a large number of new mines have been put into operation. The prospect is that other properties will be put in shape for trade.

The price paid for mining has been the highest known in the history of the State. The barge-line trade on the Warrior River has been increased materially to points in the South and Southwest. Many new steam-coal contracts have been renewed at highly satisfactory prices for 1917.

If the present rate of progress continues during 1917, that year will show the largest coal and coke production Alabama has ever had. Interruptions by reason of the flood conditions in July, 1916, caused several of the important operations to suspend for several months. The Gulf States Steel Co. is about to complete 39 by-product ovens of the Koppers type. There are many beehive ovens scheduled to start as soon as the necessary preparations can be made.

Arkansas.[2]—The production of coal for the fiscal year ending June 30, 1916, was 1,910,298 short tons, valued at $3,452,717, an increase of 210,199 short tons over the production for 1915.

The production for the calendar year exceeded 2,000,000 tons. Owing to the location of several smelters at Fort Smith, the coal trade in Sebastian County looks brighter now than ever before in the history of the State. The use of soft coal at the smelters has been instrumental in opening several strip pits near Midland and Hartford. This coal could not be marketed as a commercial fuel until the smelters entered the field.

Colorado.[3]—During the past year there has been a decided improvement in the whole tone of the business. Notwithstanding the fact that in that period the output increased 1,545,551 tons, the operators were unable to entirely fill the demands made on them. The normal annual production of the State is in the neighborhood of 10,000,000 tons and but for several serious obstacles that hampered the production of the mines, this would have been exceeded by fully 10 per cent.

[1] C. H. Nesbitt, *Coal Age*, Jan. 13, 1917, p. 44.
[2] Thomas H. Shaw, *Coal Age*, Jan. 13, 1917, p. 45.
[3] A. R. Tibbitts, *Coal Age*, Jan. 13, 1917, p. 45.

PRODUCTION OF COAL IN THE UNITED STATES

State.	1914.		1915.		1916.
	Quantity.	Total Value.	Quantity.	Total Value.	Quantity.
Alabama	15,593,422	$20,849,919	14,927,937	$19,066,043	16,500,000
Arkansas	1,836,540	3,158,168	1,652,106	2,950,456	1,730,000
California, Idaho, and Nevada	8,170,559	13,601,718	12,503	32,054	15,000
Colorado	8,170,559	13,601,718	8,624,980	13,599,264	10,450,000
Georgia	166,498	239,462	134,496	231,861	174,000
Illinois	57,589,197	64,693,529	58,829,576	64,622,471	64,500,000
Indiana	16,641,132	18,290,928	17,006,152	18,637,476	19,000,000
Iowa	7,451,022	13,364,070	7,614,143	13,577,608	7,900,000
Kansas	6,860,998	11,238,253	6,824,474	11,360,630	7,400,000
Kentucky	20,382,763	20,852,463	21,361,674	21,494,008	25,330,000
Maryland	4,133,547	5,234,796	4,180,477	5,330,845	3,700,000
Michigan	1,283,030	2,559,786	1,156,138	2,372,797	1,230,000
Missouri	3,935,980	6,802,325	3,811,593	6,595,918	3,950,000
Montana	2,805,173	4,913,191	2,789,755	4,526,509	3,200,000
New Mexico	3,877,689	6,230,871	3,817,940	5,481,361	4,750,000
North Dakota	506,685	771,379	528,078	766,072	626,000
Ohio	18,843,115	21,250,642	22,434,691	24,207,075	37,000,000
Oklahoma	3,988,613	8,204,015	3,693,580	7,435,906	3,470,000
Oregon	51,558	143,556	39,231	111,240	40,000
Pennsylvania, bituminous	147,983,194	159,006,296	157,955,137	167,419,705	175,000,000
South Dakota	11,850	20,456	10,593	16,384	15,000
Tennessee	5,943,258	6,776,573	5,730,361	6,479,916	6,560,000
Texas	2,323,773	3,922,459	2,088,908	3,445,487	1,800,000
Utah	3,103,036	4,935,454	3,108,715	4,916,916	3,500,000
Virginia	7,959,535	8,032,448	8,122,596	7,962,934	9,850,000
Washington	3,064,820	6,751,511	2,429,095	5,276,299	2,970,000
West Virginia	71,707,626	71,391,408	77,184,069	74,561,349	91,000,000
Wyoming	6,475,293	10,033,747	6,554,028	9,555,804	7,500,000
Total bituminous	422,703,970	493,309,244	442,624,426	502,037,688	509,162,000
Pennsylvania, anthracite	90,821,507	188,181,399	88,995,061	184,653,498	88,312,000
Grand total	513,525,477	681,490,643	531,619,487	686,691,186	597,474,000

MANUFACTURE OF COKE IN THE UNITED STATES
(In short tons)

State.	1914.			1915.		
	Beehive Coke.	By-product Coke.	Total Coke Produced.	Beehive Coke.	By-product Coke.	Total Coke Produced.
Alabama	1,052,614	2,031,535	3,084,149	1,001,477	2,070,334	3,071,811
Colorado	666,083	0	666,083	670,938	0	670,938
Georgia	24,517	0	24,517	20,039	0	20,039
Illinois	0	1,425,168	1,425,168	0	1,686,998	1,686,998
Indiana	0	2,276,652	2,276,652	0	2,768,099	2,768:099
Kansas	0	0	0	0	0	0
Kentucky	247,182	196,777	443,959	284,516	241,581	526,097
Missouri	0	0	0	0	(a)	(a)
Montana	0	0	0	0	0	0
New Jersey	0	255,283	255,283	0	(a)	(a)
New Mexico	362,572	0	362,572	389,411	0	389,411
New York	0	457,370	457,370	0	684,461	684,461
Ohio	67,838	453,800	521,638	19,101	665,557	684,658
Oklahoma	0	0	0	0	0	0
Pennsylvania	18,074,057	2,184,336	20,258,393	22,530,567	3,092,295	25,622,862
Tennessee	264,127	0	264,127	233,705	23,268	256,973
Virginia	780,984	0	780,984	629,807	0	629,807
Washington	(a)	(a)	(a)	(a)	(a)	(a)
West Virginia	1,381,675	46,287	1,427,962	1,250,235	141,211	1,391,446
Maryland	0	87,852	87,852	0	313,283	313,283
Massachusetts			....	0	504,438	504,438
Michigan			....	0	(a)	(a)
Minnesota	414,322	1,804,883	2,219,205	0	127,847	127,847
Utah			....	478,459	1,753,523	2,095,430
Wisconsin			....			
Total	23,335,971	11,219,943	34,555,914	27,508,255	14,072,895	41,581,150

(a) Included in combined states.

The greatest difficulty is in supplying fuel for steam purposes, for which lignite slack was extensively used. The first grade of this commodity is now selling at $2.65 per ton f.o.b. Denver, and the second grade at $2.40 per ton. It is reported that only 25 per cent. of the present demand for lignite coal is being supplied, and the supply of this fuel is limited on the local market to each day's receipts.

In the south, where the great bituminous mines are located, the price for the best grades is $5.75 and the second grade $5.50 per ton. The Colorado Fuel and Iron Co., the largest producer of the State, was slow in making any increases, desiring to establish a steady price for its best grade at $5.50 per ton. However, in Fremont County, which ships an excellent grade of semibituminous coal, the Canon City coal of the Colorado Fuel and Iron Co. advanced in price from $5.50 to $6 per ton. Lignite slack being practically unobtainable at any figure, bituminous slack is in strong demand.

Illinois.[1]—From an operating viewpoint 1916 was a year of problems, starting off with many disappointments, followed by annoyances, and finishing up exceptionally well in a financial way with troubles that while minor were numerous.

There were many unreliable forecasts of what the new wage scale would be, and these kept the operators guessing and figuring on ways to combat some of the anticipated grievances that the mine workers talked about introducing.

When the Illinois miners met in Peoria in March they had many demands to take up. The convention adjourned to New York City. From the very start of the conferences, however, there were indications that there would be no suspension, and this belief proved to be correct.

Wage increases in Illinois were as follows: Machine mining—Danville district, from 51 to 54 cts.; Central Illinois, 54 to 57 cts.; Southern Illinois, 50 to 53 cts. Pick mining—Danville district, 61 to 64 cts.; Central Illinois, 61 to 64 cts.; Southern Illinois, 57 to 60 cts. The day workers got an increase of 5 per cent. instead of the 20 per cent. asked. The dead-work increase to the miners was 5 per cent. The Illinois operators stood firm in refusing the weekly payday and the 8-hr. day.

One of the facts brought out at the New York meeting was that while the cost of living had gone up about 11 per cent., the miner who rented company houses paid the same rent as for several years past in spite of advancing taxes, increased cost of maintenance, etc.

The great problem facing Illinois operators is to find a logical market for an increasing tonnage. Crowded out of the Gulf markets by the non-union fields of Alabama and Kentucky, the Illinois producers have

[1] Abstracted from *Coal Age*, Jan. 13, 1917, p. 46.

been forced to realize that their market is drawing closer every year as regards permanent business.

The non-union competition of the South can not be overcome with an ever-increasing wage scale. There has been thought given to proposing to the miners that on coal produced to meet non-union competition the union officials allow a debate arrangement with the operators. This tonnage could be easily ascertained by railroad records.

Increasing rates to the Northern and Western markets are slowly forcing Illinois coals out of Kansas and Nebraska. None goes to North Dakota now, and South Dakota and Minnesota are letting up on it in favor of Eastern coals via the Lakes. The Chicago and Alton R.R. came to the relief of its operators in the Springfield district by reducing the rate on steam coal from $1.90 to $1.25 to Kansas City, Mo. This caused much bitterness among the operators in the Southwestern districts of Missouri, Kansas, Arkansas and Oklahoma. They fought against this invasion of their logical market but lost before the Interstate Commerce Commission. The Interstate Commerce Commission also upheld the 5½-ct. increase proposed last year by the railroads on St. Louis shipments and ordered for Sept. 1 an increase in rates of 5 cts. to all Illinois, Indiana, Wisconsin and Michigan points, thus giving the dock shippers an advantage in the Lake regions. West of the river the increase was 10 cts. a ton. There has been a continual fight against increasing rates, but the railroads always win.

While there has been no general complaint about the prorating of equipment by the railroads, some of them have been disagreeable in placing the records of distribution data at points where they are inconvenient for inspection. The Baltimore & Ohio R.R. took a case to the State supreme court, refusing to comply with the rulings of lower courts that it must change its method of distributing coal cars to mines in Illinois. The railroad gave cars in proportion to the shipments of each mine for the preceding year. The court ordered cars furnished for the needs of the mines, regardless of past shipments.

With several big railroads putting in stokers for screening on their engines, the Illinois operators see some relief in realizing a reasonable price for this size both summer and winter. The Chicago, Burlington & Quincy R.R. is the chief coal-carrying road that is rapidly putting these in, and screenings that in the past were dumped on the market during the autumn months, for little more than the cost of freight, will continue to grow in demand. Locomotives eat up coal in cold weather, and there will seldom be a surplus, for the big roads are arranging for special storage plants. The Frisco System out of St. Louis will start 1917 with a large number of stoker-fed engines.

Several mines were equipped this year with crushers to reduce mine-run or other surplus sizes to locomotive stoker size.

In the Standard field of St. Clair, Washington, Randolph, Clinton, Madison and Bond Counties there were changes, failures, sales and re-sales, openings and reopenings and all kinds of troubles too numerous to mention. One of the producers of the Standard field, who was forced into bankruptcy on account of the poor coal market, will come out with over $50,000 to the good after paying his creditors in full. This is the Joseph Taylor Coal Co., of O'Fallon. The firm is dissolved, one mine abandoned, and two other companies operating the other two mines. The Mt. Olive field of Macoupin, Montgomery and Christian Counties, where great conservative operations exist, developed no unusual conditions. There were a few changes and reopenings and many extensive improvements.

The conditions in the Springfield district with Sangamon, Logan, Macon and Menard Counties, as well as the Peoria field further north with Peoria, Tazewell and Fulton Counties, were much the same as those in the Standard field, but not so pronounced as to failures. These fields have been coming forward more in the manner of successfully conducted business operations than formerly. They have their operating bureaus, which systematize the cost of mining and marketing coal under all conditions. Heretofore this was largely guesswork.

The Harrisburg field of Saline and Gallatin Counties continues in a conservative way and with an increased tonnage. There was little out of the ordinary in this district the past year other than the gradual preparation for the further development of Saline County near the Williamson County line. Some big projects are under way here that 1917 may see fulfilled. These operators are for the most part organized as in other districts. Gallatin County is not in as a whole, being like Williamson County, where about one-third of the operators are not members of the bureau.

Indiana.[1]—The output of coal, and the mining industry in general, in the State of Indiana, during the fiscal year ending Sept. 30, 1916, was much better than was expected during the summer months. There was some time lost in April, when the new wage scale went into effect, the miners being dissatisfied with the mine-run clause in the new contract, claiming that it meant a reduction.

Notwithstanding the time lost in 1916 on account of the slight demand during the summer months, the above-mentioned strikes, and a car shortage, the total production of coal from mines employing 10 or more persons was 18,238,256 short tons. This is the greatest number of tons

[1] Michael Scollard, *Coal Age*, Jan. 13, 1917, p. 49.

produced in a single year in this State. In this State the stripping system is used where the overburden can be removed economically by steam shovels or other mechanical means, thus exposing the coal. There were 10 of these plants in operation at the close of the fiscal year. One of the largest plants of this kind is operated by the Globe Mining Co. and is located 1½ miles southeast of Staunton, on the Pennsylvania R.R. From 14 to 40 ft. of overburden is removed from what is known as the No. 3 bituminous coal, which ranges from 5 to 7 ft. in thickness. The capacity of this plant is about 20,000 tons of clean coal per month. Many others produce from 2000 to 10,000 tons monthly.

Three new bituminous mines were sunk and placed in operation during the fiscal year. There were four bituminous mines in process of sinking. These will be equipped with the latest mining machinery and will be large producers. Several smaller mines are also under construction in the vicinity of towns and cities to take care of the local trade. Seven bituminous mines and two block-coal mines were abandoned during the fiscal year.

Iowa.[1]—In the early part of the year 1916 good business in the production of coal prevailed in anticipation of a suspension in the industry after Mar. 31, while the new wage scale was being perfected and adopted. Considerable coal was stored by the railroads and the larger manufacturing companies in January, February and March. As a consequence of this the demand for coal was light during the months of April, May and June, and while there was no suspension in mining as was anticipated by some, the demand was so slight that mining operations were almost at a standstill. The months following showed a fair demand for coal, which demand increased during the remainder of the year, October, November and December proving the best months in the Iowa coal industry for years.

In the agreement made in April, 1916, between the operators and the miners, the State of Iowa was put on a mine-run basis in coal mining. This necessitated a change in the tipples at many of the mines, so that the coal could be screened after weighing instead of before weighing. This change threw some of the mines idle for a short period during the summer, while the change was being made. The production for the year for this reason may have been cut down a little, but probably not in any great amount.

Kansas.[2]—The deep mines in Crawford and Cherokee Counties produced about 80 per cent. of the entire coal production of the State. All the mines in these two counties are worked on the room-and-pillar system and the coal bed will not average 3 ft. in height, while considerable faulty work is encountered.

[1] L. E. Stamm, *Coal Age*, Jan. 13, 1917, p. 50.
[2] John Pellegrino, *Coal Age*, Jan. 13, 1917, p. 51.

The coal mines in Leavenworth, Osage and Linn Counties are small. The coal runs from 12 to 30 in. in height and is worked on the longwall system of mining. Twelve new mines were opened during the past year.

The conditions of the coal market of the State are unusually bright, but it is impossible to supply the coal market at the present time on account of a shortage of cars or flats. Some of the mines have only been working half time during the past 60 days on account of being unable to get sufficient flats to run them.

At the present time there are 22 steam shovels at work stripping coal in the State of Kansas and several new shovels are being put in. The production of the steam-shovel strip pits in Kansas will reach about 1,000,000 tons for 1916.

Some labor disturbances occurred in this State during the year. The district officials of the United Mine Workers of America called a strike at all the Western Coal and Mining Co.'s and Weir Coal Co.'s mines. This was settled satisfactorily after the men were on strike a short time. There were a number of small strikes at several mines, but these were of short duration and were quickly settled.

Kentucky.[1]—The estimated tonnage of coal produced in Kentucky for the year 1916 is approximately 25,106,500 tons. The western portion of the State contributed 7,524,400 tons, Christian, Daviess, Henderson, Hopkins, Ohio, Union and Webster Counties being included in this section. These figures indicate a loss of 61,000 from the preceding year, due to the strike in Muhlenberg and Ohio Counties.

The southeastern section contributed 6,763,300 tons, including Bell, Harlan, Knox, Laurel, McCreary and Whitely Counties. This tonnage indicates a gain of more than 600,000 over the 1915 production, which is less than would have been produced had there been no car or labor shortage.

The northeastern part of the State produced 10,818,800 tons, from the following counties: Boyd, Breathitt, Carter, Floyd, Jackson, Johnson, Lawrence, Letcher, Morgan, Perry and Pike. The gain from these counties was nearly 3,300,000 tons over the preceding year.

The 1916 output of Kentucky exceeded that of 1915 by approximately 4,000,000 tons, despite labor and car shortage. The labor shortage was not serious, although one company figures its production was curtailed 250,000 tons on this account, and 60,000 tons due to car shortage.

Shipments from the western part of the State went almost exclusively to Southern markets, but a comparatively good tonnage went to southern Indiana and Illinois. Similar shipments from the southeastern district went principally to Tennessee, Georgia, North and South Carolina, but a

[1] C. J. Norwood, *Coal Age*, Jan. 13, 1917, p. 52.

notable headway was made in shipments north of the Ohio River to the West and Northwest. A relatively small percentage of the production of the northeastern district went to Kentucky points, the shipments going chiefly to Ohio, Michigan, Indiana, Illinois and the Northwest, some also going to Canada. Quite a considerable tonnage went to by-product ovens in Kentucky, Michigan, Wisconsin and Illinois, and some shipments were made to Tidewater.

The curtailment of the output of individual companies from August to November inclusive ranges from 20 to 60 per cent. From the reports received it is probable that with an adequate car supply, which would also have helped the labor situation, at least from 2,000,000 to 2,500,000 tons would have been added to the output of the State.

Maryland.[1]—The estimated amount of coal produced in Maryland during 1916 was 4,930,000 tons.

The various seams of coal worked during the year were as follows: The Pittsburgh, or Big Vein; the Sewickley, or Tyson; the Lower Kittanning, or Davis, 6-ft.; the Bakertown, or Barton, 4-ft.; the Upper Freeport, or Thomas, 3-ft.; the Waynesburg; the Clarion, or Parker; the Brookville, or Bluebaugh, and the Little Pittsburgh.

During the year five new companies were organized and began shipping coal. In Alleghany County 31 companies operated 70 mines; in Garrett County 10 companies operated 15 mines. Thus in the state 41 companies operated 85 mines in two counties.

Michigan.[2]—The estimated production of Michigan coal this year is about the same as last year—1,056;393 tons. There are 16 mines in operation at the present time, with three new mines being sunk. These new shafts will tap large basins of coal and it is expected employment will be given to a large number of men.

There is no scarcity of labor in the mines just now, but during the summer months the industry was badly handicapped on this account. The railroad car service was about 95 per cent.

There were 191 accidents reported for the past year up to the latter part of December, two of which proved fatal. The mines are in good condition, and the indications point to a good winter with a very fair price for coal.

Montana.[3]—For the year ending Oct. 31, 1916, there has been more coal produced in Montana than in any previous year in the history of the State, the year 1913 being the nearest competitor, with a production of 3,365,712 tons. This year the output of coal was 3,688,307 tons, an increase over 1915 of 1,000,000 tons.

[1] J. L. Casey, *Coal Age*, Jan. 13, 1917, p. 53.
[2] Thomas Kanary, *Coal Age*, Jan. 13, 1917, p. 53.
[3] John Sanderson, *Coal Age*, Jan. 13, 1917, p. 53.

Most of the coal operators of the State have advanced the price of coal at the mine from $3.50 to $4 per ton, and the demand is in excess of the supply. Coal is selling in Helena at $8 per ton, with the prospect of the price going higher.

New Mexico.[1]—The total production of coal for the year ended Nov. 1, 1916, amounted to 3,893,185 short tons. This is a slight increase over the production for the preceding year. Of this production 53,445 tons was anthracite, 3,084,478 tons bituminous, and 755,262 tons semi-bituminous. The approximate value at the mines is given as $5,694,807.

During the year 2,897,822 tons was sold on the market, 965,042 tons was made into coke and 30,321 tons was used in operating the mines.

A great deal of complaint has been heard about the shortage of labor at the mines in New Mexico, but it is doubtful if the shortage has curtailed the output to any appreciable extent. For while some of the small producers claim that they have not been able to fill their orders, the largest producers report loss of time for lack of orders.

Colfax is the only county in the State that produces any coke. The St. Louis, Rocky Mountain & Pacific Coal Co. here operates 410 ovens and produced 193,282 tons of coke. The Stag Canon Fuel Co. operates 570 ovens and produced 285,871 tons of coke. The total tonnage of coke for the year was 479,153 tons, valued at $1,486,878.

Ohio.[2]—The year just closed has been one of unusual activity throughout all the mining districts of the State. With a few minor exceptions, the coal mines have been worked with remarkable freedom from strikes and disputes. Estimates based upon information obtained from the best available sources in the various districts of the State, indicate that the total tonnage for the year will aggregate between 30,000,000 and 31,000,000 tons or an increase of 8,000,000 tons, which is about 35 per cent. over the production of the preceding year, 1915.

This substantial and gratifying increase does not fully measure the prosperity that has prevailed in the industry, especially during the latter part of the year. The tonnage of that period might well have equaled, if not exceeded, that of 1913 if it had not been for the lack of railway equipment.

During the year 1916 the Lake trade was more than ordinarily active. Had it not been for the car shortage, the tonnage of the year would no doubt have surpassed that of former years. Many of the Ohio coal operators are taking advantage of the present era of prosperity to extend the markets for Ohio coal in fields heretofore ignored.

The long-continued suspension of the mines located in the counties

[1] W. W. Risdon, *Coal Age*, Jan. 13, 1917, p. 54.
[2] J. H. Pritchard, *Coal Age*, Jan. 13, 1917, p. 54.

of Belmont, Harrison and Jefferson continued well into the year 1915, but at last a satisfactory wage-scale agreement was entered into between the operators and representatives of the United Mine Workers at Cleveland, Ohio, May 11, 1915. This remained in force until Apr. 1, 1916. However, the price of coal even after the settlement did not justify the large mines of the district in resuming operations, and many of them were not operating at the close of the year 1915.

In the Hocking district, composed of Athens County and the major portion of Perry County, about 60 per cent. of the mines suspended operation in July, 1915, and remained idle until about June of the following year, the reasons assigned by the operators being their inability to compete with cheaper coal produced in other States and the existence of a discriminating railroad rate against Ohio coal.

On Mar. 9, 1916, an interstate agreement was made covering prices and conditions of mining in western Pennsylvania, Ohio, Indiana and Illinois for the 2 years beginning Apr. 1, 1916, and ending Mar. 31, 1918. The Pittsburgh Vein Operators Association of Ohio for their mines in Belmont, Harrison and Jefferson Counties, Ohio, then entered into an agreement with the United Mine Workers of America, the contract becoming effective Apr. 1, 1916, and ending Mar. 31, 1918. At Logan, Ohio, on Apr. 25, 1916, an agreement was signed for the Hocking Valley district to cover the same period of time.

The shortage of labor was no doubt due, in a large measure, to the conditions prevailing during the preceding 2 years, 1914 and 1915. Long strikes in what is known as the No. 8 field and a suspension of the major portion of the mines in the Hocking Valley during portions of those years had caused large numbers of employees to seek work in other fields. Many of these, no doubt, established themselves in their new homes. Moreover, other men were called by their mother countries to become participants in the European conflict.

Oklahoma.[1]—In the year ended June 30, 1916, 3,053,543 tons of coal was produced from the mines of Oklahoma. This is a decrease in the production from the previous year of 268,252 tons. In 1915 there was also a falling off of 410,757 tons. Of the 1916 production, 1,957,722 tons was obtained by pick mining, while 1,058,320 tons was obtained from machine mines. This is an increase of machine-mined coal of 287,566 tons.

Reports were received from 98 mines, of which 31 operations report a production of 30,000 or more tons per annum. There are 16 mines with an average daily production of over 300 tons. The largest average daily production is 842 tons and is reported from the Rock Island Coal

[1] Edward Boyle, *Coal Age*, Jan. 13, 1917, p. 57.

Co. No. 40 mine, located at Gowen, Okla., while the M. K. & T. Coal Co. No. 19, at Wilburton, follows with a record of 811 tons.

Pennsylvania Anthracite.[1]—The production of anthracite in 1916, as estimated by the Anthracite Bureau of Information shows a slight decrease as compared with the preceding year, but the total quantity sold and delivered to consumers exceeded that of 1915 by more than 10 per cent. These somewhat unusual conditions arose from the fact that the winter of 1914–15 was exceptionally mild and was followed by a period of depression, so that although the production was maintained at practically a normal rate, the market for the greater part of the year refused to absorb it and the surplus was sent to storage yards that were in many cases already well filled.

With the advent of cold weather in November and December of 1915 and the prospect of a suspension of operations on Apr. 1, when the wage agreement of 1912 terminated, demand improved somewhat and some storage coal was sent to market; but as a result of the conditions that prevailed in the earlier months of 1915, the year 1916 opened with an unusual quantity of coal on hand, the amount in storage being variously estimated at from 6,000,000 to 8,000,000 tons. The first 3 months of 1916 showed an increase in production over the corresponding period in 1915.

In April, however, on account of considerable idleness among the miners, while the wage agreement was in process of adjustment, the output was nearly a quarter of a million tons less than in the same month of 1915. In the 4 summer months of May, June, July and August the production of 1916 was slightly more (about 250,000 tons) than in 1915, though in neither year was the production or shipments up to normal for that season. During this period in 1916, however, demand for anthracite had been unexpectedly stimulated both by manufacturing industries (due to a shortage of bituminous coal) and by domestic consumers who, warned by the experience of the previous winter, which had been in marked contrast to that of 1914–15, had indicated an intention to make their fuel provisions for the coming winter in advance, and at the same time take advantage of the summer discounts.

About the same time, as a result of the call for labor from munition plants and other industries, a serious shortage, particularly of miners and miners' helpers, developed in the anthracite region, many operators eventually finding their labor forces depleted by as much as 25 per cent. Production fell off materially in the last few months of the year, the output for that period in 1916 being about 2,000,000 tons less than for the corresponding months in 1915.

[1] E. W. Parker, *Coal Age*, Jan. 13, 1917, p. 58.

The unusual demand, for the reasons stated, absorbed not only the entire production, but the storage-yard supplies and in November an entirely unnecessary panic, accentuated by sensational newspaper cries of an impending anthracite famine, developed. The fact is that although the production from the mines and washeries in 1916 was about 600,000 tons less than in 1915, this quantity was made up approximately 10 times over by the shipments from the storage yards, and the quantity of anthracite actually marketed in 1916 was the largest in the history of the trade. There is also probably more anthracite in the cellars of consumers at present than at any previous time for this season of the year.

Some complaint of car shortage and of inadequate transportation facilities was heard during the panicky period, but as practically all of the coal mined and in the storage yards was sold and distributed, any serious defect upon the industry due to such cause is not apparent.

Pennsylvania.[1]—The number of employees in the bituminous region was 171,477 and in the anthracite 155,689. There were 418 fatal accidents in the bituminous region and 517 in the anthracite, also 1673 non-fatal accidents in the bituminous region and 1379 in the anthracite. There were no great disasters to mar the remarkable record of the industry.

The year was one of feverish activity, sharp contrasts in prices and exasperating uncertainty due to car shortage, labor troubles and embargoes placed upon traffic. To most operators, however, it was a period of almost unprecedented prosperity, the demand for coal reaching abnormal proportions and prices in many cases climbing to high figures.

The European War, with its far-reaching influences, gave a great impetus to nearly all lines of manufacture, and the necessity for large quantities of coal on short notice put a heavy strain on the operators. Those who were properly equipped with mining facilities and were not tied up by previous contracts at moderate prices have had a year of golden opportunity. A word should be said here in commendation of the operators who held fast to the low prices on contracts entered into before the abnormal conditions arose. Many operators faithfully and religiously fulfilled their obligations, although they received probably only $2 a ton, while $4 or $5 was the tempting price held out to them by the over-prosperous and unusually active manufacturers.

When bituminous coal reaches $6.50 a ton at the mine, as was the case in many instances, with a general average of $5, the heyday of prosperity would seem to have been reached for the operators, who, under normal conditions, frequently find it hard to get one-third as much. There has,

[1] Frank Hall, *Coal Age*, Jan. 13, 1917, p. 60.

in fact, been a beseeching appeal for coal from the Atlantic to the Pacific, with prices a secondary consideration.

The anthracite region was also agreeably affected by the great wave of business activity, and the operators reaped rich results. Anthracite in some localities was at a premium several times during the year, with the price in New York at $12 a ton and at other points $10.

The coke production may reach 22,000,000 tons and, if so, will establish a new record. This great output was accomplished, too, in spite of labor and car troubles. The trade felt the quickening impulse of the unusual conditions and every effort was made to meet the demand. Prices in the Connellsville region reached an extremely high mark. Spot coke attained $7.50 and foundry spot $8 at the ovens. The early contract prices were less than half these figures.

In the Eastern and New England regions the car shortage at times was acute and a coal famine seemed imminent in New York at one time. The railroads were short of cars and took no immediate steps to remedy conditions.

ESTIMATES OF BITUMINOUS AND ANTHRACITE PRODUCTION AND PERSONS EMPLOYED IN MINES DURING 1916

	Bituminous.			Anthracite.		
Districts.	Production (Net Tons).	Employees.	Coal Consumed at Mines, Tons.	Production (Net Tons).	Employees.	Coal Consumed at Mines, Tons.
First	4,000,000	4,900	86,000	2,792,837	5,911	328,006
Second	7,080,000	6,650	181,000	3,963,226	5,287	340,849
Third	3,285,000	3,500	185,000	2,738,944	5,236	396,733
Fourth	5,500,000	5,800	183,000	2,482,096	5,061	369,572
Fifth	7,291,500	6,605	210,000	2,952,709	6,801	250,920
Sixth	5,040,024	5,379	133,532	3,387,668	7,189	367,174
Seventh	4,126,050	6,162	149,850	2,840,915	6,550	268,167
Eighth	6,336,957	6,771	84,399	3,661,433	8,790	370,707
Ninth	7,000,000	6,250	211,000	2,764,559	6,232	383,737
Tenth	3,534,095	4,849	247,188	2,574,884	5,673	341,682
Eleventh	8,500,000	7,000	240,000	3,175,390	5,634	541,721
Twelfth	5,568,498	6,524	226,568	3,791,608	7,173	488,506
Thirteenth	4,290,000	4,580	90,000	3,547,616	7,345	329,884
Fourteenth	3,129,595	4,070	382,084	3,607,757	7,349	325,501
Fifteenth	5,436,889	6,156	82,183	4,083,339	6,621	628,321
Sixteenth	5,500,000	8,700	750,000	3,059,239	7,529	427,360
Seventeenth	4,752,217	5,486	128,548	3,433,465	6,222	318,779
Eighteenth	4,500,000	6,900	235,000	2,010,215	3,543	320,846
Nineteenth	6,820,000	5,545	138,000	3,000,000	5,000	325,000
Twentieth	4,249,936	4,650	110,000	3,063,451	6,349	445,539
Twenty-first	7,258,950	7,740	590,700	2,900,000	5,500	300,000
Twenty-second	4,358,200	3,915	207,900	3,499,312	7,712	607,686
Twenty-third	7,200,000	7,900	210,000	2,345,000	6,060	349,000
Twenty-fourth	5,655,373	4,472	300,729	2,320,999	5,722	354,412
Twenty-fifth	5,239,220	5,069	110,522	2,393,877	5,200	393,877
Twenty-sixth	4,508,456	4,918	84,900	....	....	....
Twenty-seventh	5,250,000	5,250	63,000	....	....	....
Twenty-eighth	5,275,798	5,280	175,065	....	....	....
Twenty-ninth	4,675,888	4,591	128,047	....	....	....
Thirtieth	5,412,295	5,865	144,270	....	....	....
Totals	160,774,741	171,477	6,068,485	76,390,539	155,689	9,574,179

The lack of cars, together with a scarcity of workers, due largely to the call made upon the foreign miners by their home governments, created early in the year a condition that augured ill for the operators in their efforts to meet the unusual demands for coal.

In various sections of Pennsylvania, labor troubles added to the anxieties of the operators and rendered more difficult the keeping of contracts. It is probable that the various drawbacks that injected themselves into the operations of the year lessened the production by 3,000,000 tons.

Texas.[1]—During the year 1916 there were in operation in the State of Texas 18 bituminous and 32 lignite mines. Two bituminous and three lignite were abandoned, while five new lignite mines were opened.

The approximate total output of the mines of the State was 1,200,000 tons of bituminous coal and 1,100,000 tons of lignite. The coal and lignite business of Texas is still suffering from the competition with natural gas and fuel oil, which governs the output to a great extent. No coke ovens are operated in Texas.

Utah.[2]—The production of coal in the State of Utah for the fiscal year 1916 was 3,621,935 tons, an increase of 538,259 tons, or 17 per cent., over 1915 and an increase of 332,680 tons over the production for 1913, which was the record coal-producing year for the State until the present year.

The coke production was 424,294 tons, an increase of 66,722 tons, or 18 per cent.; 5460 tons of this amount is in storage.

An average of 3511 men at the mines and 225 men at the coke ovens were employed during the year—a decrease of 308 men compared with 4044 men for 1915.

There were 22 fatal accidents during the year, or 5.88 per thousand men employed. This is an increase of 11 accidents compared with 1915. Thirteen wives were made widows by these fatal accidents and 47 children rendered fatherless. The majority of the children, however, were self-supporting. There were also 37 serious and 202 non-serious accidents reported, making a total of 261.

Some slight labor troubles occurred during the month of October and three mines were closed 1 day each. The miners and daymen asked for an advance per ton of mined coal and also for daywork. A general advance of 6½ per cent. was given them. The majority of the operators gave the advance voluntarily. At a number of the mines the price of coal to dealers has been raised 60 cts. per ton.

The average working time at 17 of the largest producing mines for the fiscal year was 214 days.

A serious condition, owing to the shortage of railroad cars, has con-

[1] B. S. Gentry, *Coal Age*, Jan. 13, 1917, p. 61.
[2] J. E. Pettit, *Coal Age*, Jan. 13, 1917, p. 61.

fronted the coal operators of this State since September. During the month of October the mines worked 54 per cent. of the time, and in November 61 per cent. The working of broken time, owing to the shortage of railroad cars, caused much dissatisfaction among the miners and a number of men secured employment elsewhere. At the present time the mines are working with decreased forces, but they are yet unable to get sufficient railroad cars to keep even the present force working steadily.

Washington.[1]—The production of coal in 1916 was greater than that for the previous year. By the reports received, and an estimate for December, this is shown to be about 3,000,000 short tons, as against 2,409,331 short tons in 1915. Although the production in 1916 was greater than in 1915, it was still about 500,000 tons short of the normal production over a period of 10 years.

The coke production for the year was about 95,000 short tons, as against 88,695 tons in 1915. The coke output has shown a steady increase during the past 3 years.

No labor troubles of any consequence occurred during the year. An increase of from 3 to 5 per cent. was granted to all those engaged in and about the coal mines, and a contract was signed by the operators and the United Mine Workers of America that will govern conditions for the next 2 years.

West Virginia.[2]—During the fiscal year ending June 30, 1916, there was produced in West Virginia 79,443,768 gross tons of coal and 1,957,632 net tons of coke. During the same period last year there was produced in this State 64,118,677 gross tons of coal and 1,103,004 net tons of coke. This shows that the production of coal this year has increased 15,325,091 gross tons over the production of 1915, while the production of coke rose 854,628 net tons over that of last year.

Of the coal produced this year 74,168,490 gross tons was shipped from the mines, 1,074,446 gross tons was used in the operation of the mines, 975,509 gross tons was furnished to local trade and tenants and 2,925,323 gross tons was used for the manufacture of coke. Small country mines produced 300,000 gross tons. This should be added to the amount furnished to local trade and tenants.

Of the 79,443,768 gross tons of coal produced this year 48,935,403 gross tons was produced by machine mining and 30,508,365 gross tons by pick mining.

During this same period 28,190 machine miners and helpers and 17,780 pick miners were employed, together with 2606 mining machines. Last year there were employed in this State 29,690 machine miners and helpers, and 19,777 pick miners, using 2566 mining machines.

[1] James Bagley, *Coal Age*, Jan. 13, 1916, p. 62.
[2] E. A. Henry, *Coal Age*, Jan. 13, 1917, p. 64.

During the year ending June 30, 1916, four counties within the State increased their production by more than 1,000,000 gross tons—McDowell, 5,991,405; Fayette, 2,485,633; Logan, 1,855,104, and Raleigh, 1,141,952.

A number of new developments have been started in Logan, Wyoming, Boone, Marion and Raleigh Counties.

During the year in question 399 fatal accidents occurred at the mines —370 inside and 29 outside—the principal causes of which were as follows: 224 due to fall of slate, coal and roof; 39 due to electrical motors, mining machines and electricity; 68 due to mine cars; 38 due to local explosions; the other 30 were due to various causes incidental to mining, such as mine cages, railroad cars at tipple, explosions of powder, etc.

During the year ending June 30, 1915, 455 fatal accidents occurred in this State. This shows a decrease for the year of 56. During the year ending June 30, 1916, the tonnage of coal mined per each fatality inside was 214,713 gross tons against 151,223 gross tons last year, and in the mines where fatal accidents occurred there was an average of one life lost for each 109,316 gross tons.

There occurred in this State during the year ending June 30, 1916, 1177 non-fatal accidents as against 1628 for the same period last year, showing a decrease this year of 451.

During the fiscal year just past, there were employed at the mines and coke ovens 799,964 persons, a decrease under the figures for the previous year of 1364. These employees were classified as follows: Pick miners, 17,780; machine miners, 23,899; machine runners and helpers, 4291; inside laborers, 19,570; outside laborers, 12,255; coke workers, 2169, making the total number of persons employed inside 65,540, and the total number outside, exclusive of coke yards, 12,255; coke yard employees numbered 2169.

COMPARATIVE STATEMENT OF COAL PRODUCTION FOR FISCAL YEARS 1915 AND 1916, TONS OF 2240 LB.

County.	1916.	1915.	County.	1916.	1915.
Barbour	1,096,358	962,228	Mineral	639,341	556,350
Boone	631,664	575,835	Mingo	2,938,443	2,538,174
Braxton	316,445	294,206	Monongalia	501,101	319,947
Brooke	594,909	727,326	Nicholas	182,854	122,264
Clay	479,320	531,645	Ohio	643,840	540,333
Fayette	10,367,505	7,881,872	Preston	1,246,189	980,322
Gilmer	121,036	137,971	Putnam	531,589	479,045
Grant	178,420	165,121	Raleigh	6,099,519	4,957,567
Greenbrier	35,692	24,128	Randolph	684,556	550,108
Harrison	4,813,808	4,533,032	Taylor	1,192,552	946,814
Kanawha	5,766,941	5,142,586	Tucker	1,313,348	1,453,752
Lewis	23,482	300	Upshur	140,013	98,504
Lincoln	109,406	41,966	Wayne	63,451	51,458
Logan	8,162,390	6,307,286	Wyoming	432,177	96,166
Marion	6,189,891	5,988,879			
Marshall	1,018,842	963,173	Totals	79,443,768	63,818,677
Mason	109,655	125,135	Small country mines	300,000	300,000
McDowell	18,999,079	13,007,674			
Mercer	3,519,952	2,717,510	Grand totals		64,118,677

During the year ending June 30, 1916, the mines of this State were operated 232 days against 190 days last year.

West Virginia, Northern.[1]—Throughout the year the severe car shortage has been the most important and distressing feature that northern West Virginia coal operators have had to deal with. Car distribution has been about 35 per cent. below allotment, and in spite of the great scarcity of labor it has not been possible to give the men in the region full time.

This, in the face of the increased demand for coal in general and particularly for coal of the character produced in the Fairmont region, has led to severe criticism of the railroads. The production for the year will probably be in the neighborhood of 14,000,000 gross tons, or about 10 per cent. below last year. Had it not been for the car shortage the year's output undoubtedly would have been in excess of any past performance.

Prices have fluctuated greatly and have been almost constantly abnormal. The high prices of spot coal have resulted in the opening of many small mines or country banks (familiarly known as dog holes), in some cases coal being hauled by teams several miles and loaded into railroad cars. Cars for these small mines, together with other cars bought up and held for speculative prices, has further increased the car shortage.

The Lake trade, which is probably the largest single item of the region's business, has not received its full quota of coal, as sufficient cars were not available. Consequently, there is a shortage at the Upper Lake ports. There is little likelihood, however, that this shortage will be severe, although the Northwest may have a bad scare. It is quite possible that some all-rail shipments will be necessary into the Northwest before the Lakes are again open.

There has been a continued investigation during the year concerning the use of Fairmont coal in by-product ovens. The Monongahela Valley Traction Co., which holds large natural-gas interests, has recently purchased the Baxter property of the New Central Coal Co. It is currently reported that its intention is to erect by-product ovens, using this coal, the gas from which will supplement and finally entirely take the place of its own natural gas.

There have also been transfers during the year, of large acreages of Sewickley coal lands, which were never before active in northern West Virginia, and a number of mines have been opened in this seam. Apparently there has been no difficulty in selling this coal in moderately large tonnages whenever cars could be secured. It is reported also that a number of contracts have been made for future delivery.

Developments on the Western Maryland R.R. have been watched with growing interest. Mines Nos. 86 and 87 of the Consolidation Coal

[1] H. O. Williamson, *Coal Age*, Jan. 13, 1917, p. 62.

Co., on a branch of this railroad, have been in operation for some months and mines of the same company at Wyatt, also on a branch of the Western Maryland, are being completed rapidly.

The friendly relationship that has always existed throughout the region between the workmen and the operators has been further cemented during the year by a substantial, voluntary increase in wages and a consistent and energetic effort on the part of the operators to better both working and living conditions.

Ever since the beginning of the war innumerable persons with very little or no knowledge of the coal business, have been pointing out to the coal operators the immense possibilities of coal business in Europe and South America. In northern West Virginia, at least, it would seem that the operators were thoroughly informed as to the possibilities of this trade, and also of its difficulties. Certainly they have made a strenuous effort and spent a large amount of money endeavoring not only to secure European and South American coal business, but also to put that business on such a basis that it might be retained in future years. During 1915 quite a fair showing was made in spite of the many difficulties encountered. These difficulties have steadily increased throughout 1916 and have left the foreign trade of northern West Virginia in bad shape with little prospect of any immediate improvement.

A demand has been created for the coal of this region in certain foreign markets, but it is now impossible to supply that demand. The shortage of railroad cars has been the first and greatest obstacle. Even were it possible to get cars there are no boats to be had at reasonable rates, and but few at any rate, certainly nothing like an adequate supply. For these two reasons alone there has been case after case where the operator has been simply obliged to refuse foreign orders, although the prices offered have been particularly attractive.

If any one is to be blamed for not taking advantage of the opportunities offered in the way of foreign coal trade, it is certainly not the coal operators of this region. In any event the 1916 European and South American trade of the region will be far less than that of 1915, and at the present moment it is practically at a standstill.

The explosion at the No. 7 mine of the Jamison Coal and Coke Co. at Barrackville, with a loss of 11 lives, marks the only serious accident of the year. Aside from this the accident record shows a gratifying improvement that it is hoped will continue in the future.

The opening of 1917, while it finds northern West Virginia somewhat short of labor, shows general conditions to be excellent. There is little doubt but that if it is possible to arrange for an adequate car supply the year will be a particularly busy and prosperous one.

West Virginia, Southern.[1]—The Chesapeake & Ohio and the Norfolk & Western railroads haul most of the coal from what is generally termed southern West Virginia. The local papers give the two together credit for hauling 63,000,000 tons of coal in 1916. This is probably not far from correct. The Kentucky field served by the Chesapeake & Ohio produced about 5,000,000 tons and the Norfolk & Western hauls some coal from Virginia and Kentucky, but I have omitted the tonnage handled by the Kanawha & Michigan, so a fair estimate of tonnage produced by southern West Virginia for 1916 would be something over 50,000,000 tons and in excess of any previous year.

It is of some interest to note that while May exceeded all previous records of coal hauling by the Chesapeake & Ohio, yet every month in the year shows over 2,000,000 tons. The average daily car supplies per month on the Chesapeake & Ohio indicates a gradually increasing shortage, but a settled condition of less than 50 per cent. supply for the year.

It is significant that during the months of August and September, when over 500,000 tons per month was lost on account of the flood on Cabin Creek, Paint Creek, Coal River and other streams, the coal hauled by the Chesapeake & Ohio was just as great as ever, and the car supply correspondingly better to those who were outside of the flooded region.

The Norfolk & Western has come nearer serving its mines than the Chesapeake & Ohio and has kept up its reputation of being a "coal-hauling trick." The truth is, both of these roads have done a little better than ever before, although there has been some bitter complaint of discrimination in certain sections and there is some suspicion that the roads have yielded to the natural temptation to haul coal from the easiest places instead of making an equal distribution of cars on hand.

Wyoming, District No. 1.[2]—Sept. 30, 1916, marked the closing of the most successful fiscal year in the history of coal mining in District No. 1 of the State of Wyoming. Although in the majority of the mines in this district during the past year there has been a scarcity of men, still the past year shows a greater production than for any other year in the history of Wyoming. The relations existing between the United Mine Workers of America and the operators have been cordial and mutually pleasant, and a contract was signed by both parties for a period of 2 years.

District No. 2.[3]— The coal production in district No. 2 for the fiscal year ending Sept. 30, 1916, was 2,169,512.65 tons, or an increase of 360,691 tons over the previous year. It is a safe estimate that the production for the calendar year 1916 will exceed these figures by 500,000 tons.

Notwithstanding the great loss in tonnage due to the severe car

[1] Josiah Keely, *Coal Age*, Jan. 13, 1917, p. 63.
[2] George Blacker, *Coal Age*, Jan. 13, 1917, p. 66.
[3] Abstracted from *Coal Age*, Jan. 13, 1917, p. 67.

shortage of the early part of the year, and again in the months of September and October, it was the largest production recorded for this section of the State. It is also a fact that very few of the mines now in operation have been working to their full capacity.

There were employed in the industry 2059 men, and the year as a whole was a prosperous one. Early in the spring, when the work at the mines began to slacken, many left the mines for other employment, which resulted in almost a shortage in some instances. However, as there will be an increased tonnage for the calendar year, there will also be a proportionate increase in the number of men employed.

THE WORLD'S PRODUCTION OF COAL IN SHORT TONS

Country.	1912.	1913.	1914.	1915.	1916.
United States......	534,466,580	569,960,219	513,525,477	531,619,487	597,474,000
Great Britain......	291,666,299	321,922,130	297,698,617	283,570,560	287,110,153
Germany..........	281,979,467	305,714,664	270,594,952	259,139,786	....
Austria-Hungary...	56,954,579	59,647,957	(*d*)53,396,400	(*d*)52,679,712	50,801,602
France............	45,534,448	45,108,544	33,360,885	19,908,892	(*a*)22,000,000
Russia............	33,775,754	37,188,480	36,414,560	31,158,400	128,962,724
Belgium...........	25,322,851	25,600,960	(*a*)19,000,000	15,691,465	(*a*)19,900,000
Japan.............	21,648,902	23,988,292	21,700,572	22,596,750	22,189,969
India.............	16,471,100	18,163,856	18,430,974	19,156,404	....
China.............	16,534,500	(*a*)15,432,200	....	....	(*a*)24,000,000
Canada............	14,512,829	15,012,178	13,594,984	13,269,023	14,461,678
New South Wales...	10,897,134	11,663,865	11,663,865	10,582,889	1,262,420
Transvaal (*b*)......	7,591,619	8,191,243	7,778,706	9,275,083	11,200,370
Spain.............	4,559,453	4,731,647	4,897,360	5,414,475	6,055,727
New Zealand.......	2,438,929	2,115,834	2,548,664	2,208,624	....
Holland...........	1,901,902	2,064,608	1,928,540	2,262,148	....
Chile.............	1,470,917	1,362,334	....	....	....
Queensland........	1,010,426	1,162,497	1,180,825	1,147,186	1,016,654
Mexico............	982,396	....	....	....	....
Bosnia and Herzegovina.............	940,174	927,244	....	....	....
Turkey............	909,293	....	....	....	....
Italy.............	731,720	772,802	861,265	1,042,748	....
Victoria..........	664,334	668,524	691,640	588,104	....
Orange Free State (*e*)	525,459	609,973	699,217	727,537	....
Dutch East Indies..	622,669	453,136	440,905	....	....
Indo-China........	471,259	....	....	....	....
Servia............	335,000	....	....	....	....
Sweden............	397,149	401,199	404,143	454,432	....
Western Australia..	330,488	351,687	357,515	....	....
Peru..............	307,461	301,970	312,897	318,563	....
Formosa...........	306,941	....	....	....	....
Bulgaria..........	324,511	....	....	....	....
Rhodesia..........	216,140	237,728	391,394	458,934	....
Roumania..........	....	....	....	....	....
Korea.............	....	....	....	....	....
Tasmania..........	59,987	61,648	68,130	66,000	62,244
British Borneo.....	....	49,762	128,505	....	....
Spitzbergen........	....	....	....	....	....
Brazil............	....	....	....	....	....
Portugal..........	16,938	27,653	32,743	....	....
Venezuela.........	(*a*)12,000	13,355	....	....	....
Switzerland........	....	....	....	....	....
Philippine Islands..	2,998	....	....	....	....
Unspecified........	....	....	....	....	....
Total...........	(*c*)1,377,000,000	(*c*)1,478,000,000	(*c*)1,334,000,000	(*c*)1,270,000,000	....

(*a*) Estimated. (*b*) Transvaal includes Natal and Cape of Good Hope and figures given are of coal sold only. (*c*) Approximate. (*d*) Hungarian production estimated at 10,000,000 short tons. (*e*) Represents coal sold only; probably 10 to 12 per cent. less than production.

Note.—This table is based on a compilation of the U. S. Geological Survey, supplemented by some later statistics. Most of the figures given for the years 1914, 1915 and 1916 are obtained from other sources and represent the best information available at this writing.

Coal in Foreign Countries

Australia.—The coal output of New South Wales for 1915 amounted to 9,449,008 tons, showing a decrease of 941,614 tons as compared with 1914. Exports in 1915 amounted to 4,668,394 tons as compared with 5,868,033 tons in 1914. About half of these exports were to overseas ports, the balance being to other Australian sections.

The northern district continues to be the heaviest producer, putting out 6,307,015 tons in 1915 as compared with 2,261,398 tons in the southern district and 880,595 tons in the western district. The reduction in output in 1915 was due in part to the restricted demand for coal and also to extended labor difficulties. In spite of the reduced output, however, the production of machine-mined coal showed a moderate increase, being 2,817,072 tons in 1915 as compared with 2,775,921 tons in 1914.

The State of Victoria produced 588,104 tons in 1915, showing a decrease of 29,432 tons as compared with the preceding year. The bulk of this production continues to originate from the State mines at Wonthaggi, which produced 528,922 tons during the year.

New Zealand produced in 1915, 2,208,624 tons as compared with 2,275,593 tons in 1914. Most of this coal is produced in the West Coast (South Island) inspection district, the output there in 1915 amounting to 1,278,994 tons. Of the total production in 1915, 1,267,940 tons is classified as bituminous and semibituminous, 725,000 tons as brown coal and the balance as pitch coal and lignite. No new colliery operations were commenced during the year nor any new fields of importance discovered, though large areas of coal were proved up.

The coal production of Queensland in 1915 amounted to 1,024,273 tons, showing a decline of 29,717 tons as compared with 1914. The total number of collieries at work in 1915 was 44.

Argentina.—The total imports of coal into Argentina from the United States in 1916 amounted to 921,969 tons as compared with 786,967 tons in 1915. In 1914 there was 3,421,517 tons of coal imported from all sources, which declined to 2,543,887 tons in 1915, while the 1916 figures will doubtless show a still further falling off. As was to be expected, the greatest decline in imports occurred in shipments from Great Britain, which have fallen off heavily since the beginning of the war, the tonnage in 1913 being 1,927,387 as compared with 1,266,579 in 1914 and only 525,756 tons in 1915.

Austria-Hungary.—The hard-coal production of the dual monarchy for 1915 amounted to 16,083,074 tons as compared with 15,411,369 tons in 1914. During the first 8 months of 1916, Austria alone produced 11,765,000 metric tons, which compares with 10,693,000 tons for the same period in 1915. The output of brown coal for the same period was 14,600,000 tons in 1915 and 15,800,000 tons in 1916. The results indicate that this country has succeeded in maintaining its coal output in a fairly satisfactory manner during the war period.

By far the largest proportion of the brown coal mined in Austria originates in the Carlsbad district of Bohemia, this section producing approximately 20 million tons of the total production of slightly over 24 million tons mined in the whole of Austria. The decrease in the brown-coal production for the whole of Austria in 1915 amounted to 7.3 per cent. as compared with 1914.

The production of coke in Austria-Hungary in 1915 amounted to 1,907,648 tons as compared with 2,189,913 tons in 1914. The coke output of Austria alone during the first 8 months of 1916 showed an increase of 500,000 metric tons, amounting roughly to 1,700,000 tons. This increase occurred largely in the Ostiau district.

Belgium.—Statistics emanating from German sources give the production for the first half year of 1916 as follows: Coal, 8,478,732 tons; coke, 408,812 tons; briquets, 1,077,735 tons. This compares with the full year 1915 as follows: Coal, 14,244,000 tons; coke, 484,000 tons; briquets, 1,202,000 tons.

Considerable tonnages of Belgium coal have been exported since the beginning of the war, some 700,000 tons having been shipped into Holland in 1915. The Germans started the development of a new coal field at Limbourg, including the construction of by-product ovens toward the close of 1916, but with the deportation of miners this work ceased.

Canada.—Preliminary estimates place the coal production of Canada in 1916 at 14,365,000 short tons as compared with 13,276,023 tons in 1915 and 13,637,529 tons in 1914. The increase was made almost entirely in Alberta and British Columbia, the former producing about 1,100,000 tons more, and the latter approximately 600,000 tons more, while Nova Scotia showed a loss of about 500,000 tons.

Exports of bituminous coal from this country to Canada showed a tremendous increase, amounting to 12,849,589 tons in 1916 as compared with 8,464,457 tons in 1915. Coke imports into Canada increased about 100,000 tons, amounting to 649,675 tons in 1916.

Chile.—The imports of coal into Chile show an extraordinarily heavy decline in 1915, amounting to only 411,317 tons as compared with 1,257,559 tons in 1914 and 1,540,747 tons in 1913. The heaviest decline was shipments from Great Britain, which in 1913 exported 924,430 tons to Chile as compared with only 201,718 tons in 1915. Australia exported 457,873 tons in 1913 and only 155,541 tons in 1915.

Chile has been thrown largely on her own resources for coal, due to the practical cessation of shipments from Great Britain and the heavy restrictions put upon exports from Australia. Exporters from this latter country are required to make a deposit amounting to about $24,000 per normal cargo as assurance that the coal will not get into the hands of any of the enemy countries.

China.—There are only meager data concerning the coal production of China, the best available information being a statement issued by the Chinese Ministry of Agriculture and Commerce, which estimates that the annual output is now about 24 million tons per annum, the following districts producing a million or more tons: Manchuria, 1,300,000 tons; Chihli, 2,160,000 tons; Shansi, 2,500,000 tons, and Hunan, 5,000,000 tons. If this production of 24 million tons per annum is correct, the output shows an enormous increase as compared with 1913, when the director of the Chinese Geological Survey estimated the output at 15 million tons.

The Kailan Mining Administration, which owns and operates the coal properties of the Chinese Engineering and Mining Co., as well as the government-owned properties at Tongshan, Chihli Province, have the largest and best-equipped coal mines in China. The output for the year ended July 1, 1916, was 2,667,000 tons. The profits to the Chinese Engineering and Mining Co. were £195,145, being 60 per cent. of the total profit. The developed tonnage of coal is reported at 16,500,000 tons. The various mines of the company have been equipped with electric-driven machinery and are now able to produce at the rate of 3,500,000 tons per year. The Fushun mines, near Mukden, in Manchuria, owned by the South Manchuria Railway, are now producing at the rate of over 2,000,000 tons per year.

The Chinese exports have shown a decline since the beginning of the war, the 1915 figures being 1,315,542 tons as compared with 2,500,627 tons in 1914. The imports from Japan alone exceed the exports, the respective figures being 2,976,036 tons in 1914 and 2,629,999 tons in 1915. None was received from Great Britain, which, in the preceding year, exported 92,076 tons of coal to China.

Egypt.—For the first half of 1916 the Egyptian imports of coal amounted to 369,683 metric tons as compared with 490,054 tons in the same period of 1915. The total imports in 1915 amounted to 1,700,074 tons as compared with 1,435,882 tons in 1914 and 1,721,415 tons in 1913. Practically all of the imports originate in Great Britain. The total value of the British fuel exports to Egypt in 1915 amounted to $10,427,560, those from the United States amounting to $1,425,194, these being the only two countries furnishing coal to Egypt in that year.

France.—The French coal production for 1916 is estimated at nearly 22 million tons, or about 2 million tons more than in 1915. The production increased from 1,500,000 tons in November to 1,861,000 tons in December, due entirely to the release of the miners belonging to the classes from 1891 to 1899 from military service, these men having returned to the pits. At the close of the year the miners belonging to the classes from 1900 to 1902 were also returned to the mines, so that the outlook for 1917 production is even better.

The fuel supply question in France was a most serious problem during the year. Arrangements have been considered for obtaining approximately 2 million tons a month of British coal, but owing to the scarcity of transportation facilities, the rate of imports had declined to about 1,500,000 tons per month. It was hoped, however, that this question of transportation would be relieved before very long, and in addition efforts were being made to increase the French production by the demobilization of several thousand miners from the army. Transportation facilities within the Republic itself proved inadequate during the closing months of 1916, due largely to freezing and heavy ice on the canals; but this was relieved by diverting a large number of military trucks as well as men from the army to haul coal direct to the markets.

The gradual extension of the censorship to cover statistics of all kinds has made it exceedingly difficult to obtain any authentic information concerning the coal situation. The latest data available regarding the French imports are for the first half of 1916, during which period there was 9,982,939 tons of coal, coke, etc., imported as compared with 9,193,237 tons for the first half of 1915.

The imports for the 12 months to the middle of 1916 amounted to approximately 20 million tons, while the production was about the same, so that the apparent total fuel supply for that period was slightly less than 40 million tons. The consumption for the previous year amounted to about 35 million tons, but in spite of this increase of 5 million tons, the demand was usually in excess of the supply. The requirements of the railroads, municipal plants, etc., showed no material increase, but there was a large extra call for fuel from metallurgical industries.

The wholesale price of coal in Paris in March, 1916, was $23.16 per metric ton as compared with $11.58 to $12.55 in normal times. English anthracite was quoted at $25.09 to $26.06 as compared with $13.50 under normal conditions.

Germany.—Scarcely any information is available concerning conditions in the German coal industry for 1916. Perhaps the best index to the situation is a report of the Rhenish Brown Coal Briquet Syndicate for the fiscal period 1915–16. During this time, the output of crude brown coal was 21,642,845 tons as compared with 18,898,088 tons the preceding year. An item of interest came from Breslau early in the year regarding additions to the by-product coke equipment at the Royal Coal Mine in Upper Silesia. This plant consists of 180 coke ovens, and it was planned to make an addition of 30 new ones. The coke plants of Upper Silesia produce about 2,000,000 tons of coke per annum and employ nearly 5000 men.

An announcement was also made early in the year of a prolongation of the Rhenish Westphalian Coal Syndicate until March, 1922. This syndicate was founded in 1893 with the understanding that it was to exist for only 5 years, but it has since been renewed from time to time. The syndicate includes nearly all the coal companies in one of the principal producing territories of Germany.

A statement of the German exports for 1915 shows a heavy decline as compared with 1914, the respective figures being 6,464,197 tons in 1915 and 13,296,366 tons in 1914. The reduction was due to restrictions placed on the export trade, the tonnage to Holland, for instance, being reduced from 4,783,151 tons in 1914 to 991,174 tons in 1915.

The report of the Prussian State Mines for the year ended March 31, 1915, shows that the total output of coal was 18,433,478 tons as compared with 25,174,407 tons the preceding year. The number of collieries in operation was 23, the same as in the preceding year, but the number of miners employed declined from 96,595 to 76,312. The net profits for the year ended in 1915 amounted to about $3,700,000 as compared with $13,600,000 for the preceding year.

Great Britain.—The estimated production of Great Britain for 1916 is 255,846,000 tons as compared with 253,179,000 tons in 1915 and 287,412,000 tons in 1913, the last normal year previous to the war. For the quarter of the year ending in September, the output showed an increase of 350,000 tons as compared with the previous quarter ending June, but the last quarter showed an even heavier decline, amounting to three-quarters of a million tons, which was undoubtedly due to additional drafts on the miners for military service.

The most important development in the coal industry during 1916 was the announcement of the Government toward the close of the year of its intention to take entire control of the coal mines of the country. The Government's grip on the coal industry has been gradually tightening throughout the course of the war, first in the system of licensing exports, then in the matter of limiting prices, and the extension of this scheme to French and Italian exports, and finally to the appointment of district supply committees under the control of the central committee, with full power to fix the distribution of coal.

Special efforts have been made in Great Britain to increase the output, in pursuance of which the recruiting of trained men for military service stopped for a time, and the miners have been urged to work as steadily and effectively as possible while conferences of various kinds have been held with a view to studying this problem. The only thing accomplished by these conferences has been to arrange for the Miners' Federation to designate committees at each mine to make a study of the absenteeism among the men, with power to fine the offenders.

The British export trade suffered a still heavier decline in 1916 and has decreased to a point where it is a matter of much concern. The estimated percentage of the total production exported in 1916 was only 21.1 per cent., which compares with the average of the past half century of slightly less than 25 per cent. In 1913, the last normal year previous to the war, the percentage of British coal exported amounted to 34.2 per cent., declining to 30.5 per cent. in 1914, to 23.3 per cent. in 1915 and, as noted, to 21.1 per cent. in 1916.

But while the export tonnages have been persistently declining, it is interesting to note that the value of these has increased. In 1913, the last normal year, the British exports were slightly over 98 million tons, valued roughly at 330 million dollars. In 1916 the exports were only 54 million tons, but these were valued at 335 million dollars. It will thus be seen that the trade balance to the credit of the coal industry is being successfully maintained.

This loss in export tonnage is due primarily, of course, to the limited output, resulting from the heavy draft of miners for military service and also to the increased consumption due to the large number of munition plants, and further, in a measure to the scarcity of shipping facilities. Considerable reduction has also been caused by Great Britain exerting economic pressure on certain countries as, for instance, Norway, which usually takes in the neighborhood of 2 million tons per annum, but which is now getting no British coal whatever.

Holland.—Holland produces comparatively little coal, the total production for 1915 amounting to only 2,262,148 tons, though this shows a considerable increase as compared with preceding years, the production being 1,928,540 tons in 1914, and 1,873,079 tons in 1913. The largest production was obtained from the Wilhelmina Colliery, a State mine, which output 450,298 tons in 1915.

The apparent consumption has suffered a decline due to restrictions on imports from both Germany and England, on which Holland usually relied for most of its supplies. In 1913 the consumption amounted to 10½ million tons, in 1914 to 9½ million tons and in 1915 to slightly under 9 million tons. The imports for 1915 were 7 million tons as compared

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with 11¼ million tons in 1914 and 15¾ million tons in 1913. A great deal of this loss in imports is made up by a like decline in exports, a considerable tonnage of coal being shipped into Holland for re-export. Thus the exports show a decline from 5½ million tons in 1913 to 4 million tons in 1914 and only a quarter of a million tons in 1915.

India.—The coal production of India in 1915 amounted to 17,103,932 tons as compared with 16,464,263 tons in 1914. By far the largest proportion of this output originated in Bihar and Orissa district, which produced 10,718,155 tons in 1915 and 10,661,062 tons in 1914. The next most important district is the Bengal, with 4,975,460 tons in 1915 and 4,424,557 tons in 1914.

Imports of coal into India in 1915 showed a very heavy decline due principally to a falling off in shipments from the United Kingdom. Imports in 1915 were only 173,451 tons as compared with 400,363 tons in 1914. The imports from Great Britain for these two years were, respectively, 30,149 tons in 1915 and 156,863 in 1914. Exports of Indian coal, on the other hand, have shown a substantial increase, amounting to 751,801 tons in 1915 as compared with 577,944 tons the year before. During the latter part of 1916, the Indian Government issued a decree prohibiting the exportation of the better-grade coals.

Italy.—The imports of coal and coke into Italy for the first half of 1916 amounted to 3,734,556 metric tons as compared with 4,119,110 tons in the same period of 1915 and 5,404,470 tons in 1914. The imports from the United States for the full year 1916 amounted to 1,735,072 tons as compared with 2,931,581 tons in 1915. The imports showed an abrupt falling off beginning with September, the figure for August being 218,525 tons and for September 94,430 tons, while November showed only 33,399 tons, though December recorded an increase to 73,106.

Japan.—The coal production of Japan for 1915 amounted to 20,490,-702 metric tons, showing a decrease of 8.1 per cent. over that for 1914. The decrease was due to the more limited demand in the Far East, as a result of the war.

Japanese exports have declined steadily since the beginning of the war, being 2,901,000 tons in 1915, 3,558,000 in 1914 and 3,840,000 in 1912, this latter figure being the largest ever reached. In this connection it is interesting to note that Great Britain bought 750,000 tons of Japanese coal for its fleet in the Pacific Ocean. Imports in 1915 amounted to 610,000 tons as compared with 950,000 tons in 1914 and 572,000 tons in 1913.

Norway.—The imports of coal and coke into Norway have shown a substantial increase, the total for 1915 being 3,100,000 metric tons as compared with 2,764,000 tons in 1914 and 2,482,000 tons in 1913. As a result of the further restrictions in shipments of coal to Norway during 1916 there was renewed activity in the production of peat. One new factory was built in 1915, and several old ones which had suspended operations were re-opened, but most of these produced for local consumption only. The total quantity reaching the general market probably did not exceed 10,000 tons. The average price of peat during 1915 was $6.70 per ton f.o.b. the works.

Peru.—Peru produces comparatively little coal, the production in 1915 amounting to only 318,563 tons as compared with 312,897 tons in 1914. Imports in 1914 also showed a decline, amounting to only 139,382 tons as compared with 150,660 tons in 1913, though this was due largely to restrictions on coal shipments occasioned by the operation of warships in the vicinity of that country.

Russia.—The coal output of the Urals during the first half of 1916 was the greatest in the history of the industry, amounting to 702,724 short tons as compared with 683,504 tons in 1915 and 548,915 tons in 1914. For the 12 months ending with July, 1916, the production of coal in the south of Russia almost reached the highest tonnage made preceding the war, but the shipments were very much smaller, with the result that the stocks at the mines and distributing centers showed a very heavy increase, amounting to a total of 2,298,000 tons in July, 1916, as compared with 861,000 tons in the same month of 1915.

Imports of coal into Russia have shown a most extraordinary decline since the beginning of the war. The imports amounted to 3,194,502 tons in 1914, to 47,652 tons in 1915 and to only 4050 tons in 1916. Coke imports also showed a heavy falling off, being 442,945 tons in 1914, 948 tons in 1915 and 16 tons in 1916.

South Africa.—The coal production of South Africa made a substantial increase in 1916, amounting to 10,007,473 tons as compared with 8,281,324 tons in 1915. The output of the Transvaal amounted to 6,136,913 tons in 1916 as compared with 5,502,805 tons in 1915. The output of Natal amounted to 3,066,232 tons last year as compared with 2,304,116 tons in 1915. It is estimated that about a million and a half tons of coal was used for bunkering purposes and export business, half a million tons being consumed by the railroads, the balance going into miscellaneous consumption.

In the Province of Transvaal, which produces about half of the total output, the Transvaal Coal Owners Association handled during the fiscal year ending Aug. 31, 1916, 5,462,000 tons of coal as compared with 5,047,385 tons during the previous fiscal period. The increase in bunker and export trade amounted to 179,565 tons. It is probable that of the important coal producers of the world South Africa has the lowest mining cost of any, and it is worthy of note that since the inception of the war the fuel prices have shown little or no increase, contrary to the experience of the large producing countries.

Spain.—The fuel supply question in Spain has grown rapidly more acute each year since the beginning of the war, and the most energetic efforts have been made to increase the domestic production. The output of coal in 1914 amounted to 4,424,439 tons, which was increased to 4,834,353 tons in 1915 and to 5,406,899 tons in 1916. Of the 1916 production 4,687,565 tons was bituminous, 279,521 tons anthracite and 439,813 tons lignite.

Importations of coal in 1916 amounted to slightly over 2 million tons, making the available supply about 7½ million tons, whereas the requirements amount to about 8 million tons. As a result of this shortage there have been decrees issued at different times fixing the price of coal, one of these toward the close of the year putting the maximum figure at a number of different points at $4.86 to $6.66 per ton for coal, $9.18 for foundry coke, and $7.75 for anthracite. The Spanish imports for the 6 months ending June, 1916, amounted to 1,051,775 tons as compared with 971,706 tons in the corresponding period of 1915. Coke imports declined during the same time from 117,789 tons in 1915 to 90,935 tons in 1916. So acute did the shortage become that at different times during the year the gas supply in some cities, as for instance Madrid, was cut off.

Sweden.—Fuel imports from Germany into this country for the year ending July 1, 1916, amounted to 4,404,263 tons, of which 2,204,182 tons was coal, 828,563 tons briquets and 1,312,870 tons coke. Swedish imports from Great Britain for the first half of the year amounted to 3,398,549 tons as compared with 2,242,905 tons for the same period in 1915 and 2,134,508 tons in 1914.

The annual coal consumption in Sweden amounts to approximately 4,900,000 tons, of which less than 10 per cent. is produced in the country. The production in 1913 amounted to 363,965 tons and 366,639 tons was produced in 1914.

Switzerland.—An arrangement was effected between Switzerland and Germany in September whereby the latter country agreed to provide the former with 253,000 tons of coal a month as follows: 28,000 tons of coal and briquets and 22,000 tons of coke for the federal railways, 51,000 tons of coal for producer gas purposes and 75,000 tons for industrial use. It is understood, however, that owing to poor transportation conditions in Germany the deliveries fell substantially behind these figures, and the situation, as regards the fuel supply in Switzerland, became so acute on several occasions that a reduction in the country's train service of 20 to 25 per cent. became necessary at times.

Germany has always been the chief source of fuel supply for Switzerland, the imports from there in 1914 amounting to 8,270,304 tons as compared with 815,147 tons from France, 605,113 tons from Belgium and about a quarter of a million tons each from Great Britain and Netherlands. During the same year Germany supplied Switzerland with 3,054,381 tons of coke, while France furnished 308,137 tons.

COPPER

By Walter Harvey Weed

The year 1916 was one of unprecedented prosperity and activity for the copper industry of the world, largely as a result of the World War. Prices reached the highest point known in 50 years and production, though far larger than ever before, was barely sufficient to supply the insistent, incessant demand of both war and arts. The result has been that the older developed producing mines of the world have been crowded to produce as much as possible while a multitude of small producers and many mines whose high costs of transportation or production have made their ore unprofitable in ordinary times, have joined the ranks of the shipping mines and have been feverishly worked. This condition was of very great benefit to the owners of small, or but slightly developed properties early in the year; but in the United States at least, as the older properties increased production, the smelting plants were unable—and in some cases were unwilling—to accept custom ores and the smaller producers were unable to find a market for their product. This condition has led to more or less unjust, but natural ill feeling against the smelting plants, with proposals to establish State smelters and sampling works.

As a result of the war, exact figures for the world's production are lacking, but it is probable that the Central European countries, where the metal has been scarcest, have pushed the production of copper to the utmost point possible.

The bulk of the world's production has of course come from North America, the United States furnishing 62 per cent. of the world's output, compared with 60 per cent. in 1915 and 56.4 per cent. in 1914. The total output of the United States during 1916 was 880,750 metric tons, the rest of the world producing 541,109 metric tons.

The United States production was 234,538 metric tons greater in 1916 than in the previous year, an increase of 36 per cent., this comprising most of the world's increase of 335,326 metric tons for the year, an increase of 30 per cent.

Japan, the world's second greatest copper producer, increased production 20 per cent., Canada showed a 25 per cent. increase and Mexico, whose smelters were in part again active, showed an increase of almost 80 per cent. over the 1915 production, though the total of 55,160 metric tons is less than the 1913 output. Owing mainly to American capital, Chile and Peru have also greatly increased their output.

In America the output for 1916, though phenomenal, was limited by refinery capacity. The year has been one of rapidly increasing mine output and mills and smelters have been crowded to handle seemingly impossible amounts of ore.

The price of copper at the beginning of 1916 was 22½ cts. per lb.; it increased to 25¼ cts. by the end of January, and continued war orders, contracting for much of the American output for months ahead—three orders aggregating 133,000 long tons being placed in March and April at 27 cts.—stimulated domestic buying and so cleaned up the market that spot copper reached 33 cts. in May, a price then regarded as extraordinary. A 4-months period of lower prices and little demand succeeded, several large consumers having overbought their requirements.

In September, Anglo-French contracts for 200,000 tons, or nearly one-quarter of the entire United States production, for 1917 delivery, failed to bring about any great demand, until in November insistent demands of eager buyers advanced the prices for prompt copper to 34 and 35 cts., though the major market for second quarter delivery was at 32½ cts. Because buying orders lessened at these high prices and since many consumers had contracted for 1917 copper, the German peace proposal brought about reselling and the price declined to 28¾ cts. as the year closed.

The operation of mines and smelters to the utmost capacity has brought great prosperity to all the mining districts. More men than ever before have been employed and the wage scale, based at the more important camps on the price of copper, has risen to an unheard of point, miners at Bisbee receiving $6.15 for each shift. Perhaps an equally great benefit has been the opening up of very many small properties, some of which it is probable may become steady producers.

The smelter production of copper in the United States from domestic and imported ores and scrap during 1916 amounted to 2,298,285,075 lb., compared with 1,687,027,136 lb. in 1915 and 1,398,484,346 lb. in 1914. Of this enormous total, only 37,753,760 lb. went to foreign refiners, the balance, together with 236,802 lb. of imported crude copper, being sent to American refineries. Owing to insufficient refining capacity, the production of crude copper increased faster than it could be refined and there was a shortage of nearly 200,000,000 lb., since refining capacity could not be increased quickly enough. This congestion has been partly relieved early in 1917.

SMELTERS' PRODUCTION SINCE 1912—DELIVERIES TO REFINERIES
(In Pounds)

Source.	1912.	1913.	1914.	1915.	1916.
N. American ore........	1,489,176,562	1,438,565,881	1,327,488,479	1,616,499,571	2,201,456,333
Foreign ore.	53,701,307	55,803,202	50,101,308	44,538,207	71,131,938
Scrap.................	11,949,348	22,427,889	20,894,559	15,275,991	25,696,804
Totals.............	1,554,827,217	1,516,796,972	1,398,484,346	1,676,313,769	2,298,285,075
To foreign refiners......	45,735,673	36,682,605	36,765,920	40,062,900	37,753,760
To American refiners....	1,509,091,544	1,480,114,367	1,361,718,426	1,636,250,869	2,260,531,315
Crude copper imported..	144,480,144	169,315,869	131,125,076	140,000,000	236,802,017
Total crude copper..	1,653,471,688	1,649,430,236	1,492,843,502	1,776,250,869	2,497,333,332

The copper production of the various States for the past 6 years is given in the following table:

SMELTERS' PRODUCTION OF COPPER IN THE UNITED STATES[1]
(In Pounds)

State	1911.	1912.	1913.	1914.	1915.	1916.
Alaska...........	19,412,000	32,602,000	24,452,000	24,288,000	72,621,844	115,368,191
Arizona..........	300,578,816	357,952,962	399,849,745	387,978,852	444,089,147	693,262,111
California........	36,806,762	31,069,029	32,390,272	29,515,488	37,935,893	51,428,697
Colorado.........	8,474,848	7,502,000	7,670,090	10,104,579	8,126,000	9,820,000
Idaho............	3,745,210	5,964,542	8,434,028	4,856,460	5,602,000	5,320,000
Michigan.........	216,412,867	231,628,486	159,437,262	157,089,795	241,123,404	269,888,710
Montana.........	271,963,769	309,247,735	285,336,153	243,139,737	268,027,557	353,547,696
Nevada..........	65,385,728	82,530,608	84,683,961	60,078,095	66,394,906	98,247,000
New Mexico......	1,518,288	27,488,912	46,953,414	64,338,892	75,515,138	76,955,335
Utah.............	138,336,905	131,673,803	147,591,955	153,555,902	180,951,174	226,735,520
Wyoming.........	....	1,121,109	448,805	165,023	1,020,926	2,569,000
Southern States...	19,656,971	18,592,655	24,333,014	19,213,965	18,858,677	21,142,901
Other States......	1,564,207	4,396,667	4,155,135	4,257,088	3,431,494	*17,615,425
Total..........	1,083,856,371	1,241,770,508	1,225,735,834	1,158,581,876	1,423,698,160	1,941,900,586

[1] *Eng. Min. Jour.*

* Included in other States is a good deal of copper that could not be distributed as to origin at this time.

The above figures are smelter's production, not mines, any material difference being offset by ore carried over.

All the States save Idaho show increases in their copper output, that of California being 34 per cent., Montana 32 per cent., and Utah 25 per cent., but the increase of 56 per cent. for Arizona is remarkable. Arizona is far in the lead, producing nearly double the output of Montana. Michigan continues to advance but slowly, but still holds third place.

The total production of new refined copper in 1916 was 2,259,387,-315 lb. Of this amount, 370,635,116 lb. came from foreign countries.

Refinery capacity was greatly increased in the latter half of 1916 and at the end of the year amounted to 188,000,000 lb. per month. Lake copper production was about 22,500,000 lb. per month and the output of Tennessee, Detroit-Arizona, Braden and Chuquicamata, which does not have to go through the refineries, about 14,500,000 lb. per month, gives a total product of 215,000,000 lb. of copper per month, available for consumption.[1] By June, 1917, the monthly refining capacity of the five great companies will be 240 million lb. per month, or 2,880,000,000 lb. annually.

There was also produced during the year 104,423,807 lb. of refined copper from scrap and old metal, currently called secondary copper, of which 78,585,296 lb. was electrolytically refined and the balance cast.

The total combined 1916 output of refined copper from all sources was 2,363,811,122 lb. as compared with 1,693,779,138 lb. in 1915. The production of refined copper according to class for the past 9 years is given in the following table.

PRODUCTION OF COPPER IN UNITED STATES ACCORDING TO CLASS
(In pounds)

Year.	Lake.	Electrolytic. (*d*)	Casting. (*d*)	Pig Copper. (*a*)	Total.
1909(*e*)..	226,602,134	1,101,518,458	67,471,446	43,159,018	1,438,751,056
1910(*f*)..	221,400,864	1,151,624,597	(*g*)55,673,196	46,903,463	(*g*)1,475,602,120
1911	216,412,867	1,156,627,311	22,977,534	35,920,626	1,431,938,338
1912	231,628,486	1,288,333,298	24,777,266	37,181,237	1,581,920,287
1913	155,715,286	1,037,360,178	44,966,222	36,004,986	1,652,290,541
1914	158,009,748	1,019,276,001	25,730,377	39,334,043	1,565,708,374
1915	236,757,062	1,152,502,131	42,973,030	15,047,990	1,447,280,213
1916 (*b*)	269,794,531	1,658,205,809	38,307,561	26,868,105	1,993,176,006

(*a*) Exported. (*b*) Advance statement, U. S. Geol. Surv. (*c*) Partly estimated. (*d*) Included copper from scrap and junk. (*e*) The statistics for 1909 are officially communicated to us by the Copper Producers' Association, except that to its report of 34,123,446 lb. of casting copper we have added 33,348,000 lb. reported to us by the junk smelters. The term "Lake" copper is here used to designate all copper sold in the trade as such, regardless of the process by which it is refined. (*f*) Copper Producers' Association, through *Eng. Min. Jour.*, May 6, 1911. (*g*) Includes 23,480,000 lb. from scrap.

Besides the regular refining companies, there are many plants that treat secondary material exclusively; the output of brass and other alloys of copper and of the metal itself produced by these plants in 1916, amounted to 558,000,000 lb., or a total of 662,000,000 lb. from secondary material. Nearly half the foregoing amount comes from remelting copper chips and clean scrap produced in manufacturing copper and brass articles. Adding the amount of the so-called secondary copper to the products of new copper produced by the refineries gives a grand total of 2,922,000,000 lb., as the United States 1916 supply of this metal. It may also be noted that the production of copper sulphate, the bluestone of commerce, absorbed 14,043,315 lb. of copper in 1916.

Consumption.—The apparent United States consumption of new refined copper for 1916 was 1,429,755,266 lb. as compared with 1,043,461,982 lb. in 1915 and 620,445,373 lb. in 1914. The stock in the hands of the refiners at the beginning of the year was 82,429,666 lb., and the amount refined during the year 2,259,387,315 lb., making a total available supply of 2,341,816,981 lb.

[1] Boston News Bureau.

Exports of refined copper amounted to 784,006,486 lb. and the stock on hand at the end of the year was 128,055,229 lb. Combining export and stock gives a total of 912,061,715 lb. of copper withdrawn from the supply, leaving an apparent consumption of 1,429,755,266 lb.

Foreign consumption has been very great, as shown by record-breaking purchases at unprecedented prices on this side of the ocean. It is, however, impossible on account of the war to give any figures showing European consumption. The visible supply Jan. 1, 1916, is reported as 20,064 tons. Twenty-four American brass and manufacturing concerns consume 1,554,000,000 lb. annually. Exigencies of war have undoubtedly stimulated European production to the highest possible point by all copper mines, and the British and French governments having taken over all copper stocks indicates a consumption and a scarcity of supply of wholly unprecedented character.

In the following table the consumption of copper in the United States during the past 10 years is given, together with the production and the stocks at the beginning and close of the year, imports and exports and supply.

The supply is the sum total of production, of stock Jan. 1, and of imports. The consumption is the difference between supply and the sum of exports plus stock at the end of the year.

CONSUMPTION OF COPPER IN THE UNITED STATES

Year.	Production.	Stock Jan. 1.	Imports.	Supply.	Exports.	Stock Dec. 31.	Consumption.
1907...	1,152,747,890	9,000,000	5,000,000	1,166,747,890	508,929,401	120,000,000	537,818,489
1908...	1,152,895,019	120,000,000	....	1,272,895,019	661,876,127	122,357,266	488,661,626
1909...	1,405,403,056	122,357,266	....	1,527,760,322	682,846,726	141,766,111	703,147,485
1910...	1,452,122,120	141,766,111	....	1,593,888,231	708,316,543	122,030,195	763,541,493
1911...	1,431,938,338	122,030,195	....	1,553,968,533	786,553,208	89,454,695	677,960,630
1912...	1,581,920,287	89,454,695	....	1,671,374,982	775,000,658	105,312,582	791,061,742
1913...	1,622,456,829	105,312,582	....	1,727,769,411	926,441,142	91,348,867	709,979,402
1914...	1,533,781,394	90,385,402	....	1,634,166,796	840,080,922	173,640,501	620,445,373
1915...	1,634,204,448	173,640,501	....	1,807,844,949	681,953,301	82,429,666	1,043,461,982
1916(a)	2,259,387,315	82,429,666	....	2,341,816,981	784,006,486	128,055,229	1,429,755,266

(a) U. S. Geol. Surv. estimate.

Exports.—The 1916 exports of copper ore, matte or regulus, amounted to 105,847 long tons; the exports of copper as ingots, bars and plates for the year amounted to 784,103,644 lb. The accompanying table gives the exports to the different countries during the last 6 years.

The following figures show the effect of the war upon copper exports. England and her allies took the bulk of our exports, mostly as ingots, bars, etc. The Teutonic allies, formerly our best customers, have had to rely upon the great stocks of copper imported from the United States for several years preceding the war, as is shown by the table in which in addition to the amount actually sent to Germany, most of the copper exported to Holland must be credited. In 1913 this amounted to 486,091,050 lb., or over half the total exports of the United States for that year. Exports for 1916 average 65,342,000 lb. per month.

EXPORTS OF COPPER FROM THE UNITED STATES (*a*)
Ore, matte and regulus stated in tons of 2240 lb. Ingots, etc., in pounds

Country.	1911.	1912.	1913.	1914.	1915.	1916.
Ore, matte and regulus	57,915	66,171	65,684	43,529	57,731	105,847
Ingots and scrap (*b*)						
Exported to:						
United Kingdom....	108,061,603	95,422,292	33,679,641	198,382,459	201,218,655	184,564,740
Belgium...........	5,125,004	7,674,273	7,102,120	5,429,717	....	....
France............	135,038,893	131,362,694	160,000,345	150,839,897	236,236,135	336,829,464
Germany..........	190,428,008	252,156,012	307,150,761	176,698,948	....	....
Italy..............	38,216,773	47,251,432	41,568,713	67,415,944	107,101,156	113,764,478
Netherlands........	230,693,649	152,618,177	178,940,289	126,001,150	4,018,841	5,853,306
Russia............	15,601,688	4,961,473	7,907,672	8,731,272	37,430,402	49,658,437
Austria-Hungary...	44,200,202	38,558,151	34,648,205	26,989,548	....	....
Other Europe......	9,254,363	8,960,973	14,357,014	45,634,229	56,013,517	30,700,473
Brit. North America	8,931,582	30,302,856	36,182,257	24,221,498	24,127,098	45,947,740
Other countries.....	1,001,443	5,732,325	4,904,125	9,736,260	15,771,151	16,785,006
Total...........	786,553,208	775,000,658	826,441,142	840,080,922	681,917,955	784,103,644

(*a*) The exports of ore, matte and regulus are reported as gross weight, the copper contents not being stated. (*b*) Includes bars and plates.

Imports.—The imports of copper as ore and matte during 1916 aggregate 174,787,854 lb. net,[1] compared with 114,331,441 lb. in 1915. Imports of the metal as converter bars, pigs, ingots, plates and scrap

IMPORTS OF COPPER INTO THE UNITED STATES (*a*)
(In pounds)

Country.	1911.	1912.	1913.	1914.	1915.	1916.
Ore and matte						
Imported from:						
Germany.........	....	....	1,067,024	4,684,448	....	....
Spain............	....	....	6,244,676	2,633,395	1,298,408	2,659,211
Cuba.............	....	....	5,362,132	18,659,788	28,876,226	40,644,140
Canada..........	12,919,644	28,930,073	34,072,096	24,584,124	29,591,823	37,344,754
Mexico..........	16,684,071	18,069,987	19,722,530	15,495,694	14,707,724	33,525,559
Chile............	15,305,335	26,749,545	(*c*) 25,311,542	(*c*) 30,562,839	33,435,039	44,508,322
Other countries...	23,717,628	31,122,098	17,712,105	8,180,816	6,442,226	16,105,868
Total..........	68,626,678	104,871,703	109,492,105	104,801,324	114,331,441	174,787,854
Pig and Scrap (*b*)						
Imported from:						
United Kingdom..	9,004,461	1,404,118	17,943,285	5,163,126	7,485,625	3,838,167
Other Europe.....	28,042,257	31,670,095	(*d*) 36,565,767	(*d*) 16,931,784	(*d*) 7,964,534	(*d*) 550,290
Canada..........	22,442,335	36,138,255	33,749,133	27,230,559	44,977,829	53,765,656
Mexico..........	97,115,574	124,742,193	97,003,847	43,193,868	15,973,838	62,391,123
Chile............	5,175,823	8,627,421	18,315,000	23,814,659	36,303,505	76,833,657
Peru............	42,545,031	43,891,439	42,667,436	44,488,809	61,342,067	72,892,869
Australia and Tasmania..........	22,426,670	24,700,333	22,149,335	15,130,001	443,520	....
Japan...........	20,030,447	19,511,402	14,367,493	10,918,069	17,970,768	9,528,457
Other countries...	19,197,254	14,684,336	17,298,533	14,678,628	8,905,322	7,747,907
Total..........	265,980,760	305,369,592	300,059,829	201,549,503	201,367,008	287,548,126

(*a*) The imports reported are the copper contents of ore, matte, and regulus. (*b*) Includes also bars, ingots, and plates. (*c*) All from Chile. (*d*) All from Spain.

[1] Bureau of Foreign and Domestic Commerce.

amounted to 287,548,126 lb. compared with 201,367,008 lb. in 1915. The ore shipments come largely from Mexico, Canada and Cuba, with a large tonnage from South America. The pig copper imports are mostly from the American continents, but include a very considerable amount sent over from Japan to be refined. Australia has ceased to be a factor, owing to the British war embargo. The large tonnage of ore and crude metal annually imported from Spain has dwindled as a result of war conditions.

The annual imports from the various countries of the world are given in the foregoing table.

World's Production

The copper production of the different nations of the world is presented in the following table, the figures being compiled from many sources, most of those for 1916 being taken from the *Engineering and Mining Journal.* Only the domestic productions from ores and raw products are given. No official statistics of the European countries are available for the past 2 years, such information being rigorously guarded on account of the war. The estimates presented in the table are regarded as close approximations.

THE WORLD'S COPPER PRODUCTION
(In metric tons)

Country.	1907.	1908.	1909.	1910. (h)	1911.	1912.	1913.	1914.	1915.	1916.
Africa (a) Cape Co...	4,298	4,550	4,720	7,016	17,252	16,633	5,812	3,125	*27,000	*50,000
Africa (a) Namaqua.	2,540	2,440	2,337				2,540	2,328		
Africa (a) Other.....	....	....	8,128	8,433	....	....	17,059	18,682		
Argentina (a)......	224	226	610	305	1,036	335	117	....	....	....
Australasia (a).....	41,910	40,123	34,952	40,962	42,512	47,774	47,326	37,590	32,512	*35,000
Austria-Hungary (a)	1,062	3,877	6,218	2,276	2,566	4,024	4,135	3,310	....	....
Bolivia (a).........	21,035	2,540	2,032	2,540	(d) 2,950	(d) 4,681	3,658	2,743	* 3,000	*4,000
Canada (d).........	2,540	24,376	21,626	23,810	25,570	34,213	34,587	34,027	47,202	53,263
Chile (d)...........	28,863	42,097	42,726	38,346	33,088	39,204	40,195	40,876	(f) 52,081	(f) 71,430
Cuba (d)...........	1,388	2,966	3,006	3,538	3,753	4,393	3,517	6,251	8,836	9,311
Germany—total (a).	20,818	20,523	32,815	25,105	22,363	24,304	25,309	30,480	*35,000	*35,000
(Mansfeld) (a) ..	(17,343)	(18,000)	(19,015)	(20,275)	....	....	(20,201)	....	....	....
Italy (a)...........	3,353	3,022	2,769	3,272	2,642	2,337	1,626	2,410	940	*1,000
Japan (f)...........	40,183	41,399	42,987	50,703	d) 52,303	d) 62,486	a) 73,152	68,058	75,415	81,280
Mexico—total (d)...	57,491	38,190	57,230	62,504	61,884	73,617	52,815	36,337	30,969	55,169
(Boleo) (a)......	(11,506)	(12,600)	(12,426)	(13,003)	....	....	(13,020)	....	....	....
Newfoundland (a)..	1,758	1,453	1,402	1,097	1,174	549	....	....	....	....
Norway (a)........	7,122	9,337	9,226	10,592	9,576	11,156	11,796	*11,000	(d) 32,410	.35,000
Peru (e)...........	20,681	15,240	16,257	27,375	28,500	f) 26,483	d) 25,715	23,647	*16,000	41,625
Russia (c).........	15,930	17,718	18,035	22,670	25,747	33,550	42,970	31,938	*35,000	*16,000
Spain-Portugal (a)..	50,470	53,425	53,023	51,080	51,748	59,876	54,696	37,099	....	....
Rio Tinto (a)....	32,833	35,517	35,938	(34,114)	(35,100)	....	36,901	21,515	*35,000	*50,000
Tharsis (a).......	4,206	4,500	4,425	(3,551)	(3,450)	....	3,270	....	....	....
Mason & Barry (a)	2,662	2,804	2,403	(3,003)	(2,972)	....	3,185	....	....	....
Sevilla (a).......	2,337	2,196	1,849	(1,656)	(1,558)	....	1,535	....	....	....
Sweden (c).........	1,577	2,808	2,032	2,032	2,032	3,957	6,891	4,692	4,561	....
Turkey (a).........	1,270	1,068	813	610	1,016	508	508	....	....	....
United Kingdom (g)	677	588	442	508	405	405	305	347	238	250
United States (d)...	398,930	430,399	501,372	492,720	491,634	563,260	557,387	525,529	646,212	880,750
Total..........	724,120	758,065	854,758	877,494	879,751	1,011,312	1,002,284	934,888	1,082,376	1,419,069

(a) As reported by Henry R. Merton & Co., Ltd., of London. (c) As officially reported, except for 1909, for which year the figure of Henry R. Merton & Co. is used. (d) As reported by the *Eng. Min. Jour.* (e) As officially reported 1903–1907, as per Henry R. Merton & Co. for 1908 and 1909. (f) As officially reported. (g) As officially reported, 1900–1905; subsequently as per Henry R. Merton & Co. (h) Henry R. Merton & Co., through *Eng. Min. Jour.* * Estimated.

WORLD'S PRODUCTION OF COPPER (a)

Year.	Metric Tons.	Short Tons.	Year.	Metric Tons.	Short Tons.	Year.	Metric Tons.	Short Tons.
1885....	229,315	252,828	1896...	384,493	423,917	1907...	724,120	798,205
1886....	220,669	243,295	1897...	412,818	455,147	1908...	758,065	835,623
1887....	226,492	249,716	1898...	441,282	486,529	1909...	854,758	942,408
1888....	262,285	281,179	1899...	476,194	525,021	1910...	877,494	966,998
1889....	265,516	292,741	1900...	491,435	541,561	1911...	879,751	969,750
1890....	274,065	302,166	1901...	529,508	583,517	1912...	1,011,312	1,114,769
1891....	280,138	308,862	1902...	542,606	597,951	1913...	1,002,284	1,104,517
1892....	309,113	340,808	1903...	630,590	694,910	1914...	934,888	1,018,395
1893....	310,704	342,562	1904...	693,240	764,758	1915...	1,082,376	1,193,114
1894....	330,075	363,920	1905...	698,931	770,221	1916...	1,419,069	1,564,254
1895....	339,994	374,856	1906...	715,510	788,492			

(a) The statistics for 1881–1891 are as reported by Henry R. Merton & Co.; 1892–1916 a per MINERAL INDUSTRY.

The returns from the Pan-American countries, Australia and Japan are practically complete; Mexico shows a marked increase, but the production is not yet as great as in 1910 to 1913, largely due to the disturbed conditions of the country. The great increase in Chile is due to the operations of the Chile Copper Co. and the Braden Copper Co., the former not yet operating to full capacity. Japan still holds second place and indeed has forced production to meet the insistent demands of the munition plants supplying Russia.

PRICES

The average price of copper for the year 1916 was 27.202 cts., which, large as it is, does not truly represent the actual condition of the market with its fluctuating, yet rising prices. Speculation was promptly checked in England and France by governmental prohibition and purchases. The first of these great war orders, for 43,000 tons, was made March 29, with further sales, 40,000 long tons, April 7, and 50,000 tons April 10, all at 27 cts. These transactions excited an already nervous market; by the end of April domestic buyers had driven the price to 29 cts. for July to September delivery, while spot copper brought 35 cts. in May. Overbought and nervous consumers—possibly also a few speculators—trying to re-sell their copper, brought prices down to 25 cts., relieving the previous high tension.

The statistical position of the metal was strong, however, since the tightness of the market was due principally to a lack of refining capacity, a state of affairs which it took time to remedy. Prices being uncertain, many manufactures bought only on order and worked on a toll basis, rolling mills charging 10 cts. per lb., though wire drawers got only the normal price of 1 ct. per lb.

In September, an Anglo-French order for 200,000 long tons was given for 1917 delivery. Curiously enough this did not liven up a dull market, although it was known that there was practically no copper on the market for 1916 delivery. The result was that the autumn trade forced prices from 27½ cts. at the last of October, to 34 cts. and 35 cts. for prompt delivery and 32½ cts. for second quarter 1917 delivery.

AVERAGE PRICE OF ELECTROLYTIC COPPER PER POUND IN NEW YORK (*a*)
(In cents per pound)

Year	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
1905.	15.008	15.008	15.125	14.920	14.627	14.673	14.888	15.664	15.965	16.279	16.599	18.328	15.590
1906.	18.310	17.869	18.361	18.375	18.457	18.442	18.190	18.380	19.033	21.203	21.833	22.885	19.278
1907.	24.404	24.869	25.065	24.224	24.048	22.665	21.130	18.356	15.565	13.169	13.391	13.163	20.004
1908.	13.726	12.905	12.704	12.743	12.598	12.675	12.702	13.462	13.388	13.354	14.130	14.111	13.208
1909.	13.893	12.949	12.387	12.563	12.893	13.214	12.880	13.007	12.870	12.700	13.125	13.298	12.982
1910.	13.620	13.332	13.255	12.733	12.550	12.404	12.215	12.490	12.379	12.553	12.742	12.581	12.738
1911.	12.295	12.256	12.139	12.019	11.989	12.385	12.463	13.405	12.201	12.189	12.616	13.552	12.376
1912.	14.094	14.084	14.698	15.741	16.031	17.234	17.190	17.498	17.508	17.314	17.326	17.376	16.341
1913.	16.488	14.971	14.713	15.291	15.436	14.672	14.192	15.400	16.328	16.337	15.182	14.224	15.269
1914.	14.223	14.491	14.131	14.211	13.996	13.603	13.223	(*b*)	(*b*)	(*b*)	11.739	12.801	13.602
1915.	13.641	14.394	14.787	16.818	18.506	19.477	18.796	16.941	17.502	17.686	18.627	20.133	17.275
1916.	24.008	26.440	26.310	27.895	28.625	26.601	23.865	26.120	26.855	27.193	30.625	31.890	27.202

(*a*) From *Eng. Min. Jour.* (*b*) No quotation.

AVERAGE MONTHLY PRICES OF COPPER MANUFACTURES (*a*)
(In cents per pound)

	1914.		1915.		1916.	
	Wire.	Sheet.	Wire.	Sheet.	Wire.	Sheet.
Jan.	15.94	20.75	14.80	19.50	25.70	31.00
Feb.	15.88	20.50	15.19	20.25	28.66	34.50
Mar.	15.60	20.35	16.09	20.63	29.13	34.50
Apr.	15.25	20.25	18.03	22.38	31.10	36.00
May	15.23	19.90	19.95	24.50	33.75	37.88
June	15.03	19.56	21.13	25.25	32.50	38.00
July	14.88	19.38	21.63	25.50	30.25	38.00
Aug.	14.63	18.80	19.25	23.90	31.38	37.00
Sept.	14.34	18.00	19.34	23.50	32.00	38.00
Oct.	13.34	17.38	19.28	23.50	32.35	38.00
Nov.	12.50	17.50	19.84	24.44	35.56	40.37
Dec.	14.25	18.88	21.81	26.00	37.00	42.00
Year	14.74	19.24	19.21	22.93	31.61	37.10

(*a*) *Eng. Min. Jour.*

AVERAGE PRICE OF STANDARD COPPER (G. M. B.'S) IN LONDON (*a*)
(In pounds sterling per ton of 2240 lb.)

Year.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
1905	68.262	67.963	68.174	67.017	64.875	65.881	66.887	69.830	69.667	71.406	74.727	78.993	69.465
1906	78.869	78.147	81.111	84.793	84.867	83.994	81.167	83.864	87.831	97.269	100.270	105.226	87.282
1907	106.739	107.356	106.594	98.625	102.375	97.272	95.016	79.679	68.375	60.717	61.226	60.113	87.007
1908	62.386	58.786	58.761	58.331	57.387	57.842	57.989	60.500	60.338	60.139	63.417	62.943	59.902
1909	61.198	57.688	56.231	57.363	59.338	59.627	58.556	59.393	59.021	57.551	58.917	59.906	58.732
1910	60.923	59.388	59.214	57.238	56.313	55.310	54.194	55.733	55.207	56.722	57.634	56.069	57.054
1911	55.604	54.970	54.704	54.035	54.313	56.368	56.670	56.264	55.253	55.176	57.253	62.063	55.973
1912	62.760	62.893	65.884	70.294	72.352	78.259	76.636	78.670	78.762	76.389	76.890	75.516	72.942
1913	71.741	65.519	65.329	68.111	68.807	67.140	64.166	69.200	73.125	73.383	68.275	65.223	68.355
1914	64.304	65.259	64.276	64.747	63.182	61.336	60.540	(*b*)	(*b*)	(*b*)	53.227	56.841	61.524
1915	60.756	63.494	66.152	75.096	77.600	82.574	76.011	68.673	68.915	72.601	77.744	80.773	72.532
1916	88.083	102.667	107.714	124.319	135.457	112.432	95.119	110.283	113.905	122.750	134.659	145.316	116.059

(*a*) From *Eng. Min. Jour.* (*b*) No quotation.

The acuteness of the situation which caused this extravagant rise in prices was not due to a lack of copper ore, for the prices stimulated production to an enormous extent, but the smelters accumulated stocks and their output in turn could not be handled by the refineries until increased capacity was attained.

The November price of 33¼ cts. for small lots caused many consumers to wait before contracting 1917 requirements and a dull market ensued, increased by the German peace proposal in December with reselling by consumers that caused a break to the closing quotation for the year of 28¾ cts. It is obvious that the maintenance of these inflated prices depends on the continuance of war orders, for despite a certain large demand to repair the damage of war, the world can hardly afford to absorb the great output at anything like present prices.

The average monthly prices of electrolytic copper in New York and of Standard in London, together with the average monthly price of manufactured copper, are given in the foregoing tables.

Costs.—Operations at the so-called porphyry mines, whose low-grade disseminated ores now constitute so large a part of the world's copper output, are summarized in the following table, compiled from the various company reports:

1916 Operations.	Utah Copper.	Chino.	Ray.	Nevada Con.	Miami.	Inspiration
Tons of ore milled	10,994,000	3,094,400	3,332,340	3,922,634	1,842,017	5,316,350
Tons of ore milled per day	30,038	8,455	9,105	10,747	5.019	14,850
Average copper content of ore, per cent	1.435	1.83	1.607	1.632	2.07	1.548
Average copper content of concentrates, per cent	18.71	14.82	19.914	8.983	42.492	30.688
Ratio of concentration	10.5	11.9	17.6	7.6	29.2	26.5
Total pounds copper produced	196,752,631	75,551,376	74,983,540	90,735,287	53,518,331	120,772,637
Pounds copper recovered per ton of ore	17.9	24.42	22.56	24.12	30.58	22.7
Extraction, per cent	62.34	66.59	70.20	73.87	73.88	75.33
Average milling, cost per ton, cents	37.82	64.00	55.35	55.9	58.9	195.84
Average cost of copper per pound, cents	6.95(*a*)	8.7	10.267	9.44	9.52	8.673
Ore reserves, tons	369,845,558	95,555,843	93,373,226	67,993,117	40,400,000	....
Copper tenor of ore reserves, per cent	1.41	1.656	2.03	1.59	1.98	....
Dividends paid	$19,493,880	$7,177,335	$4,337,955	$7,497,963	$4,295,905	$8,548,050
Added to earned surplus	$19,655,064	$5,350,613	$7,378,473	$7,504,087	$3,463,878	$12,681,500
Charged off for depreciation	$589,732	$315,213	$367,738	$433,309	$663,406	1,281,469

(*a*) After deducting miscellaneous income.

The following list gives the sellers of the copper product of the United States and of the foreign companies owned in this country. The figures given are for the 1916 output and are in round numbers only.[1]

[1] *Eng. Min. Jour., Jan.* 6, 1917.

AMERICAN SMELTING AND REFINING CO.

Utah Copper	206,000,000
Kennecott	112,000,000
Braden	43,000,000
Nevada Consolidated	92,000,000
Ray Consolidated	78,000,000
Chino	76,000,000
Cerro de Pasco	72,000,000
Chile Copper Co	43,000,000
Magma	9,000,000
Custom Ore	153,000,000
Miscellaneous (imports, etc.)	162,000,000
Total	1,046,000,000

UNITED METALS SELLING CO.

Anaconda (includes North Butte)	340,000,000
Inspiration	122,000,000
Greene-Cananca	62,000,000
Arizona Copper Co	48,000,000
Tennessee	18,000,000
Miscellaneous	7,000,000
Total	597,000,000

PHELPS, DODGE & CO.

Copper Queen, Detroit, Moctezuma, Burro Mountain	185,000,000
Calumet & Arizona	62,000,000
Total	247,000,000

CALUMET & HECLA

Calumet & Hecla, Osceola, Tamarack, Ahmeek, White Pine, Isle Royale, etc.	160,000,000

L. VOGELSTEIN & CO.

United Verde	60,000,000
Cons. Arizona	10,000,000
Miscellaneous (custom ore and imports)	90,000,000
Total	160,000,000

AMERICAN METAL CO.

Granby	45,000,000
Old Dominion	41,000,000
East Butte	18,000,000
Shannon	10,000,000
Miscellaneous (smelter products and imports)	55,000,000
Total	169,000,000

ADOLPH LEWISOHN & SONS

Miami	54,000,000
Shattuck-Arizona	18,000,000
Total	72,000,000

BEER, SONDHEIMER & CO.

Various small mines, imports, etc	30,000,000

DIRECT

U. S. Smelting Co	30,000,000
Copper Range	55,000,000
Quincy	20,000,000
Mohawk and Wolverine	19,000,000
Total	124,000,000

In addition to the above, the small outputs of the Mountain Copper Co. are sold by Jardine, Matheson & Co., and of the Utah Metals Co., by E. P. Earle.

Copper Mining in the United States

Alaska.—In 1916 the 18 producing copper mines of Alaska yielded 550,000 tons of ore, yielding 115,368,191 lb., compared with 86,509,312 lb. in 1915,[1] the output coming from the Copper River properties of the Kennecott Copper Co. overshadowing all other producers. There were three producers more in 1917 than in the year previous.

The output from many of the lesser properties was limited by inadequate transportation facilities and by the unwillingness or inability of the smelters to accept larger shipments. Were it not for these conditions many of the lesser companies would have very naturally increased their production and many mines would have become producers.

Copper River District.—This district in the Kotsina-Chitina copper belt contains many copper properties, including the wonderful deposit of the Kennicut Bonanza mines, the Jumbo and Mother Lode mines. The Kennecott Copper Corporation owns the Bonanza and Jumbo mines, whose extraordinary rich glance ores occur in limestone near a greenstone contact. The size of these ore-bodies of high-grade glance is phenomenal and the cost of production of copper per pound has been exceedingly low, averaging about 4½ cts. Besides this rich smelting ore, the mines contain much low-grade material, averaging about 10 per cent. copper, which is concentrated in a 700-ton mill to a 50 per cent. product with an 85 per cent. recovery. The tailings are treated in a leaching plant.

Prince William Sound.—The eight copper mines of this district producing in 1916 include the Beatson, Bonanza, Ellamar and Midas and five lesser mines. The total value of this product together with that of the eight small producing gold mines was $3,000,000, compared with $1,340,000 in the previous year.

Ketchikan District.—There were seven producing mines in this district in 1916, including the properties near Sulzer and other localities on Prince of Wales Island, all of which have been as vigorously worked as the sales contracts permitted.

In Southwestern Alaska several copper deposits of the Iliamna region were operated, but no ore shipped.

Arizona.—Arizona is not only the premier copper producing State, but its output exceeds that of any other country in the world. The production of 693,262,111 lb. compared with 459,972,295 lb. in the previous year, an increase of 50 per cent., is far surpassed by the increase of 135 per cent. in value, the unprecedented prices giving the 1917 output a

[1] Figures from *Eng. Min. Jour.* Geological Survey figure for 1916 is 120,850,000 lb.; for 1915 70,600,000 lb.

value of nearly $190,000,000, compared with $80,495,152 in the preceding year. This great increase was in large part due to the Inspiration and the United Verde Extension mines. The former with an output of 120,000,000 lb. is the largest single producer in the State, treating 14,000 to 17,000 tons of ore a day and ending 1916 with a yield of 11,000,000 lb. of copper a month. Another new producer, the United Verde Extension at Jerome, had an output of 25,000,000 lb.

The many smaller mines of the State have been able to operate and their combined shipments have been considerable. Unfortunately for the development of the mining industry of the State, the custom smelters have not been able to handle this excess as the ores from the company's own mines and that supplied by contract have not only crowded the plants to capacity, but in some instances forced a great accumulation of ore on the stock pile.

While great activity has prevailed at all of the camps, the extraordinary discoveries of high-grade ore in the United Verde Extension mine at Jerome led to a feverishly speculative period with the formation of many new companies, a few of which being well financed, are in a position adequately to prospect their holdings. At the close of the year, there were over 50 companies having properties in this district, of which number probably 40 were selling stock.

Similarly at Superior, in Pinal County, the Magma mine opened up an ore-body 35 ft. across on the 1400-ft. level that averages 10 per cent. copper, and the stock rose in 3 days time from $16.50 to over $50 a share. This stimulated the formation of many new companies to develop the surrounding area.

The Ajo District.—Development and construction work in this old gopher-holed copper camp continued throughout 1916 in anticipation of beginning production early in 1917. There are two companies, the New Cornelia Copper Co., controlled by the Calumet & Arizona, and the Ajo Consolidated. The former company owns an extensive area of monzonite porphyry surrounded by rhyolite and lesser amounts of other igneous rocks. The monzonite carries stringers and disseminations of chalcopyrite and bornite largely oxidized near the surface. The Ajo property shows numerous well-mineralized veins, ½ to 3½ in. thick, in rhyolite.

The New Cornelia ground has been proven by 84 diamond drill holes, 200 to 1000 ft. deep, and by 77 50-ft. test pits. This work has proven 40,000,000 tons of 1.5 per cent. ore, two-thirds of it oxidized, sulphides coming in at water level.

A plant to treat 15,000 tons daily is under construction and went into commission about the middle of June, 1917. The treatment, planned as the result of handling 12,000 tons in the experimental plant put up in 1915, may be summarized as follows:

The crude ore is broken in one large and five smaller gyratory crushers and is carried by conveyors to storage bins where it is fed to 4-ft. Symons disc grinders that reduce it to ¼ in. This material is leached in the open in 12 lead-lined concrete tanks, each 88 ft. square, 15 ft. deep, holding 5000 tons. The ore is leached by a 3 per cent. sulphuric acid solution which passes successively from tank to tank, treating the oldest charge first, at the rate of 8000 gal. per min. From the last tank of the series, the solution passes to the tank house, where it passes longitudinally through 158 lead level tanks, 30 ft. long, 4 in. wide and 5 in. deep, with lead anodes and copper cathodes. The iron and alumina taken up in this work is kept down to a workable limit by discarding a certain amount of solution, passing it over scrap iron before it is discharged.

The leached ore is removed at the rate of 500 tons per hr. from the tanks by a Hulett 10-ton clamshell bucket excavator, operating on a walking beam and travelling on rails level with the mill floor. Each load is scooped, lifted clear and carried to the dump car at the end of the track.

The company town of Cornelia and the open towns of Gibson and Clarkson contiguous thereto, are connected with the main line of the Southern Pacific railroad, 45 miles distant, by the Tucson, Cornelia & Gila Bend Railway (owned by the Calumet & Arizona Copper Co.), completed in 1916.

Mining is by steam shovels from three hills, known as Number one, two and three and some ore has been shipped to Douglas.

The New Cornelia is the first company to treat low-grade oxidized ores by leaching. A score of years ago a number of small plants were put up in Arizona to treat oxidized ores by a wet method, the most ambitious plant being erected near Miami by the Black Warrior Co. All the plants proved failures and it was not until the past 4 years when the experimental work by all the great companies, the large tails leaching plant at Anaconda and the ore leaching plant of the Butte & Duluth Co. at Butte showed what could be done, that confidence was felt in the commercial utilization of familiar chemical work.

By many people this development at the New Cornelia plant and that of the Chile Copper Co. at Chuquicamata is believed to mean the gradual passing away of our great copper smelting plants.

Bisbee.—The Phelps, Dodge Corporation, succeeding Phelps, Dodge & Co. is one of the largest copper producers of the world, operating as the Copper Queen Mines at Bisbee, with a smelting plant at Douglas, the Detroit Copper Mining Co. at Morenci, the Moctezuma Copper Co. at

Nacozari, Mex., and the Burro Mountain Copper Co. at Tyrone in the Burro Mountains of New Mexico. The company also owns the Bunker Hill Mines Co. at Tombstone, Ariz., the Commercial copper mine and the Senator gold mine near Prescott, the Stag Canyon Fuel Co. and the Phelps, Dodge Mercantile Co.

The combined output from all of these properties in 1916 amounted to 152,263,729 lb. copper, compared with 140,478,000 lb. in 1915. The total output from the smelting plant was 247,303,587 lb., as it includes the returns of custom ore from many small producers. This was sold at an average price of 24.48 cts.

The Calumet & Arizona Mining Co., at Bisbee, in its annual report for the year ending Dec. 31, 1916, gives the following figures of production and cost: copper produced, 74,898,000 lb.; silver, 1,863,000 oz.; gold, 46,377 oz. Custom ores yielded 4,196,000 lb. copper, 595,414 oz. silver and 14,704 oz. gold.

Cost of copper after deducting precious metals is given as 9.04 cts. per lb. and the average price received was 24.698 cts. Total receipts for the metals were $20,587,940 and expenditures, $9,431,405, leaving a net profit of $11,156,535. Four dividends amounting to $5,777,296 were paid in 1916. The mining property is valued at $28,582,993 and the smelting plant at $2,217,181. The sulphuric acid plant and additions to the smelter are valued at $1,159,925 and the investments in New Cornelia Copper Co. and New Cornelia & Gila Bend Railway Co. amount to $5,600,441. Other assets are notes and accounts receivable, $1,045,-613; at mines, smelter, $653,749; cash, $2,643,570; copper, silver, gold in process, $3,898,136. Copper in process is figured at 12½ cts. per lb. and silver at 50 cts. per oz.

Underground development during 1916 aggregated 125,282 ft., as compared with 93,789 ft. in 1915. Under the sliding wage scale, miners received a maximum of $5.85 per day in December as compared with $3.60 in 1914.

In the Globe-Miami district, the Miami Copper Co. increased its production from 4200 tons to 5600 tons of ore a day, the 1916 output being 1,842,017 tons of 2.07 per cent. ore yielding 53,518,331 lb. of metal, an increase of 11,699,075 lb. over 1915.

The shrinkage stope method used in the northwest part of the Captain ore-body, has been replaced by the top-slicing method in the eastern part of the mine and a large part of the output is now drawn from the 420-ft. or first tramming level.

Costs have increased from 8½ cts. per lb. in 1915 to about 9.5 cts. in 1916, owing to a 50 per cent. increase in the price of powder and 15 per cent. in timber; and the very material increase in labor which is paid for at \$3.50 per day when copper is 14 cts. per lb. and advances 12½ cts. for each 1-ct. increase in the price of copper, the rate, January, 1917, being \$5.50 per day. Owing to the greatly increased tonnage treated, costs have been kept down to 9.52 cts. per lb. for the year's output. The ore treated in November, 1915, was 2.18 per cent. and in the same month in 1916, treating 170,000 tons instead of 130,000 tons, the ore averaged 2.13 per cent. J. Parke Channing gives the costs for November, 1916, as 26 cts. for supplies, 74 cts. for labor, 47 cts. for milling, 18 cts. for general expenses and 2.3 cts. for smelting.[1] Ore reserves, Jan. 1, 1917, consist of 16,400,000 tons of 2.4 per cent. ore; 28,000,000 tons of 1.06 per cent. and 6,000,000 tons of 2 per cent. ore carrying oxides. The flotation mill handles 120,000 to 127,000 tons monthly that carry about 1.12 per cent. copper, yielding about 1500 tons of 41.5 per cent. concentrate.

The milling practice of the company is changing slightly, rolls being eliminated and Chilean mills replaced by Hardinge mills, the ore being crushed to ¼-in. and fed directly to these mills. The recovery in concentration is 73.88 per cent.

The Inspiration Copper Co. has become the largest single producer in Arizona and its production has contributed largely to the greatly increased output of the State. Starting operations in July, 1915, an increasing number of the 1000-ton units of the mill have successively been put into operation. Starting the year 1916 with a production at the rate of 64 million and ending with an output at the rate of 140 million pounds of copper per year, an average daily output of 14,000 tons of ore. The mill will eventually handle 20,000 tons of ore per day and the company now is second only to Utah Copper in the tonnage handled.

The production of 122,500,000 lb. of copper produced in 1916 came from 5,316,000 tons of ore that averaged 1.55 per cent. copper, making 200,000 tons of concentrate averaging 30.69 per cent. copper with recovery of 75.33 per cent. The result of such mammoth operations is seen in the low cost of 8.67 cts. per lb. of copper produced.

Globe.—The Globe district proper, though overshadowed by the mammoth operations at Miami, has not declined in importance, though the lesser companies, the Arizona Commercial, Iron Cap and Superior & Boston, are not yet assured producers.

The Old Dominion Copper Co., the first big producer of the Globe district, continues to keep up its output of 1100 tons of ore per day, producing somewhat better than 3,000,000 lb. of copper per month from direct smelting and from concentrating ores, the latter going to the

[1] *Eng. Min. Jour.*, Feb. 3, 1917.

Miami smeltery. The production for 1916 was 40,437,000 lb. of copper, at a cost of 9½ cts. per lb.

The mine output comes mostly from the 12th and 16th levels on the west side. No ore has as yet been found in the vein on the 1400-ft. level between the Gray and Copper Hill shafts, but other development work near the Gray is satisfactory.

The mine workings are 1800 ft. deep, though the K shaft will soon be 1950 ft. deep and the A shaft will soon be sunk to that level. The mine water, amounting to 4,000,000 gal. daily, is an important factor in the milling operations of other companies.

The Superior & Boston property, in the eastern part of the Globe district, was operated largely by lessees in 1916, for while development work was continued on the 800-ft. level, it was mainly to open up the ore-body 70 ft. above that level. Shaft sinking was continued to the 1400-ft. level. During the fiscal year ending Sept. 30, 1916, the property produced ores to the value of $207,622, all but $40,500 coming from work done by lessees. The large amount of water to be pumped still remains the main hindrance and largest item of expense. Development and mine expense, etc., aggregated $110,970; receipts for the year of $313,000 included "calls" $237,840, interest $5190, ore sales $40,500. The books show a balance on Oct. 1 of $176,107, compared with $29,529 in 1915.

The Arizona Commercial has made good developing ore on both sides of the big fault. Production for 1916 was 4,178,474 lb. of copper, from 48,889 tons of ore averaging 5 per cent.

Jerome District.—This district, long known as the site of the United Verde mine, became the locus of an old-time mining promotion boom in 1916, largely as a result of the opening up of the large and remarkably rich ore-body of the United Verde Extension Co.

Unmindful of the history of the district and the rusty wrecks and buildings that mark former booms, the public bought stock in new companies formed over night and owning but options on claims. In one week 19 permits to sell stock were issued to Jerome companies by the Arizona Corporation Commission. So-called engineers made glowing reports on ground devoid of even a trace of mineral and on which no valid location could be made and promoters rang the changes on the many after-dinner stories concerning the United Verde mine and on the new bonanza of the United Verde Extension property.

The result of this fever of speculative stock selling has been that several new companies are adequately financed for a 2-year campaign of development work on properties of real speculative value, while a few of the wilder of the wild-cat companies have been put out of business by the Corporation Commission, their funds spent in advertising, telegraph tolls, commissions and salaries, and the stock worthless.

Among the really meritorious development companies, the Jerome Verde, Green Monster, Verde Combination, Dundee Arizona, Gadsden and Jerome Pacific may be mentioned. These and several others not yet fully financed, own their property and are spending their funds in well-planned exploration work. Unfortunately the excitement has led to many false statements and gross exaggerations concerning the district in the daily press and in the so-called mining press.

Up to date of writing, not one of these companies, excepting the United Verde, United Verde Extension and Copper Chief mines, has developed a body of commercial ore. The Jerome Verde is quite likely to do so and other companies have "showings," but the reported "strikes" are so far mere stringers, bunches and spots of copper minerals.

The United Verde Extension Co., which was organized to seek the faulted downthrown continuation of the United Verde ore-body, developed a deposit whose size and value make it a property of the first rank. The first shaft was a failure, but high-grade ore was found on the 1200-ft. level of the Edith, or new shaft, in 1915 and in January, 1916, the crosscut on the 1400-ft. level encountered the richest ore-body found in the district. The ore-body is about 200 ft. by 300 ft. with an area of 60,000 sq. ft. on the 1400-ft. level. It is a new and distinct ore-body which runs into oxidized ore at 60 ft. above the 1300-ft. level and is proven below the 1400-ft. level. It is conservatively estimated that 1,000,000 tons of 16 per cent. ore are actually developed. A winze sunk 200 ft. below the 1400-ft. level passed through 114 ft. of 15 per cent. ore, 46 ft. of low-grade ore and into chalcopyrite ore. Development work for 1916 aggregated 12,193 ft.

Production for 1916 totaled about 25,000,000 lb. of copper at a cost of 8½ cts. per lb. and yielded $9,949,918. Operating expenses were $2,542,755.

A three-compartment concrete-lined working shaft is under construction and a smelting plant will be built in 1917 at a site 2½ miles from Clarkdale, a long tunnel connecting mine and smelter.

The Copper Chief mine, operated by the Hayden Development Co., completed its mill to treat the gold-silver ores of the oxidized part of its ore-body and shipped low-grade sulphide ore to the Humboldt smelter.

Outside of the Jerome district, the largest producers of Yavapai County are the Consolidated Arizona Smelting Co. mines, near Mayer, and the Binghampton, or Stoddard mine, also near that town. The Consolidated Arizona Co. operates a smelter at Humboldt and two copper mines near Mayer. In the company's annual report for the year

1916, the copper production is given as 11,989,139 lb., silver, 150,012 oz., and gold, 5972 oz., being more than double the production of 1915 and five times that of 1914. The output from the De Soto and Bluebell mines aggregated 5,829,500 lb. of copper, the balance coming from custom ore. Ore reserves at the end of the year are given as 479,500 tons in the Bluebell mine and 103,500 tons in the De Soto mine. During the year $359,482 was expended in new construction, equipment and improvements. The net profit for 1916 was $859,014.

The Stoddard mine, recently acquired by the Arizona Binghampton Copper Co., began operations in August, 1916, treating 125 tons of ore per day in a modern flotation mill, operated by electric power. The copper occurs as chalcopyrite in a flaky chlorite schist, the material as milled averaging 2 per cent. copper.

Ray District.—The Ray Consolidated Copper Co. mined 3,400,000 tons of ore during 1916 yielding 76,000,000 lb. of copper. At the beginning of 1917, the ore reserves were estimated at 71,911,475 tons averaging 44.7 lb. per ton. A recalculation of reserves made during 1916 by adding blocks hitherto insufficiently developed for calculation, though within the drilled area, has added 20,000,000 tons of 1.5 per cent. ore, making the total ore reserves Dec. 31, 1916, 93,373,226 tons of 2.03 per cent. ore, equivalent to 1,895,500 tons of copper.

Extraction was but 50 per cent. up to the beginning of 1916, but the installation of a froth flotation plant and changes in the plant during 1916, raised the extraction during the last 3 months of the year to 75.32 per cent. of the copper content, or about 83 per cent. of the copper present in unoxidized form. This increased saving has, however, been accompanied by an increased cost per pound, partly because of the expense of oil flotation and partly because of higher prices for supplies and labor. The cost per pound for the last half of 1916 is figured by the company at 10.058 cts., but the cost up to the end of 1916, figured by the *Engineering and Mining Journal*, is 10¼ cts. on a production of 220,000,000 lb. of copper.

In the latter half of 1916, 1,721,100 tons of ore milled averaged 1.61 per cent. copper and the costs of mining and coarse crushing were 8.379 cts. per ton and of milling 54.99 cts. per ton.

An increased capacity of 25 per cent. over the amount for which the mill was designed, the result of the general crowding of all producers to take advantage of high prices, has probably hindered an even better extraction and lower costs. Earnings for the last 6 months of the year were based on an average price of 26.88 cts. per lb.

Leasers working at many exposures of oxidized ore on a basis of $1 per unit for ore delivered at the railroad tracks, are mainly responsible for a production of 1,561,680 lb. of copper in the last half of the year from ore shipped direct to the smelter.

The company's mill is at Hayden, the ore being hauled 9 miles to Ray Junction over the company's railroad, then over the Arizona Eastern (S. P.) tracks to Hayden Junction where it is transferred back to company tracks.

The Ray Hercules Co. has completed its development by drilling and has sunk a main working shaft preliminary to the opening up of the ore-body for actual extraction. A concentrator is under construction at Kelvin and there is every reason to expect actual production in 1917.

The Morenci-Clifton district resumed production in February, after a period of labor trouble that bordered on insurrection and drove the mine manager from the State, as a result of the encouragement given the rioting strikers by the State authorities.

The production of the Detroit Copper Co. is merged in that of Phelps, Dodge & Co. The Arizona Copper Co., a Scotch concern, treated 905,486 tons of 1.803 per cent. ore in 1916, and produced 34,144,840 lb. of copper, as compared with 37,416,010 lb. from 968,566 tons of 1.96 per cent. ore in 1915, 38,942,455 lb. in 1914 and practically the same in 1912.

The Shannon Copper Co. had a very prosperous year and despite the fact that its copper output cost 18.461 cts. per lb. to produce, the company made a clear profit of $824,054 for the year. For the 11 months of 1916 the mine was operating, it produced 9,364,968 lb. of copper, 1327 oz. gold and 62,935 oz. silver.

The company has $1,034,835 in cash and quick assets, receiving $30,271 income from interest compared with payments of $18,000 to $20,000 annually for interest in former years. The company has acquired all but $104,000 of the bonds of its railway line, the Shannon Arizona.

Superior District.—The Magma Copper Co. produced 8,473,580 lb. of copper in 1916 at a cost of 10.803 cts. per lb., compared with 6,046,459 lb. in 1915. The total net profits were $1,097,333, an increase of $485,-604 over 1914. During the year, the crosscut on the 1500-ft. level showed the vein to contain a width of 35 ft. of 10 per cent. ore with bands of solid bornite. This ore was proved by raises and winzes for 100 ft. or more above and below the level, making it one of the really big ore-bodies of the State. This strike sent the stock from about $18 a share to over $50 a share in 3 days. The company has pursued a very conservative policy, but its property is no longer a small mine. The company recently acquired control of the Lake Superior & Arizona Co. and its property adjoining the Magma. There are as yet no other steady producers in the camp.

The old Silver King mine is being re-opened and a small flotation mill has been built to treat the old dump.

The entire mountain front from the Silver King mine southward for 6 miles or more has been acquired by new companies and active exploration work is in progress.

In the lesser copper camps of Arizona, there has been great activity. In Yuma County, the Planet mine, near Bouse, has been a producer, and the Swansea, or Clara mine, has yielded from 150 to 200 tons daily, shipped to the Humboldt smelter. The Little Butte mine, now owned by the United Mines Co. of Arizona, has been re-opened and ore shipped. The Critic and other mines near Wenden, the Mammon Gold & Copper Co. and the Arizona Empire Co., both near Parker, have been intermittent shippers.

In Yavapai County outside of Jerome, the Bluebell and De Soto mines of the Consolidated Arizona Smelting Co. have been the chief producers, but the Stoddard, or Buckingham mine, near Mayer, has been equipped with a flotation plant and become a steady producer.

At Copper Creek near Mammoth, there is renewed activity, the New State Mining Co. taking over the properties formerly owned by the Calumet Copper Creek Co. and adding the Childs group to the holdings.

Shipments of very high-grade ore have also been made from the Sombrero Butte mine, 2½ miles southerly and the Southwestern Inspiration Co., whose name is misleading, has started a campaign of stock selling to finance the development of their claims.

California.—The copper industry of this State prospered to an unprecedented extent, production reaching 51,428,697 lb. compared with 37,935,893 lb. in 1915. The well-known mines of Shasta, Plumas and Calaveras Counties were the principal producers, the Mammoth Copper Co. properties and smelters operating to full capacity. This company purchased the Stowell mine near the Balaklala, the two properties producing 500 tons daily, treated in the Kennett smelter. An electrolytic zinc plant was built by the Mammoth Copper Co. to treat the zinc ore of its copper mines.

The Mason Valley Mines Co. purchased the Gray Eagle mine near Happy Camp, Siskiyou Co. and the Walker mine in Plumas County was acquired by the International Smelting Co.

Idaho.—Copper mining is as yet one of the minor industries of this State. Idaho produced a trifle over 8,000,000 lb. of copper in 1916, compared with 6,978,713 lb. in 1915. This small change represents an increase from $1,221,275 to $2,184,000, or about 79 per cent. in value. The larger part of the output came from the old White Knob property of the Empire Copper Co. near Mackay, Custer County, and the newer producers a few miles north, operated by the Copper Basin Mining Co. Development at both properties is reported to be very satisfactory.

The Empire Copper Co. has employed over 200 men throughout the year, the output of 8000 tons a month of 4 to 10 per cent. ore going to Salt Lake smelters. This company is building a mill and flotation plant. Dividends of $250,000 were paid in 1916.

The Copper Basin Mining Co. employs about 20 men and shipped 30 cars of 4 to 15 per cent. ore in 1916.

In Shoshone County, the National mine having proved a failure, all operations were suspended. Its history is a warning to investors. The new producers in the county are the Empire Copper Co., operating a new 150-ton mill on the Little North Fork of the Coeur d'Alene River, 12 miles west of Kellogg and shipping 25 per cent. concentrate.

The Richard mine, 20 miles east of Mullan is also a producer, yielding several carloads of 10 to 15 per cent. ore. This and the adjoining St. Lawrence mine are now consolidated. The Caledonia and Horst Powell are also copper producers.

In Custer County, the Lost Packer is practically the only producer. There has been but little change in conditions in the Seven Devils district and the properties nearby.

Michigan.—The copper output of Michigan during 1916, according to figures given by the United States Geological Survey, amounted to 269,794,531 lb. compared with 238,956,410 lb. in 1915.

The Copper Country of Michigan enjoyed the most prosperous year of its history in 1916, largely as a result of the foresight of the mine managers whose preparations in 1915 resulted in an increased output while the advanced prices permitted several companies to operate profitably and earn a substantial surplus, in marked contrast to the losing work of former years.

The most important event of the year was the completion and operation of the 1000-ton ammonia leaching plant by the Calumet & Hecla Co. This is not merely a metallurgical achievement and advance, but together with the successful application of froth flotation to the Lake Superior ores, it ensures the long and prosperous future of the district. The success of the leaching method, for the plant is to be doubled in capacity, and of a method of modified oil flotation to these ores, means that the great quantity of rock in which the copper occurs in very thin flakes and disseminations, of which very large amounts occur not only in the proven parts of the range, but in its extension to the south and west, will be profitably worked.

Two methods of copper extraction have increased the life of the

Michigan copper mines and made possible a new era of mine development and production.

COPPER PRODUCTION IN MICHIGAN
(Pounds of fine copper)

Mines.	1908.	1909.	1910.	1911.	1912.	1913.	1914.	1915.	1916.
Adventure..	90,870	*Nil*	*Nil*	*Nil*	8,727,312	....	....	....	*Nil*
Ahmeek....	6,280,241	9,198,110	11,844,954	15,196,127	16,455,769	9,220,874	13,643,605	21,800,492	24,142,158
Allhouez...	3,047,051	4,031,532	4,655,702	4,780,494	5,525,455	4,091,129	6,056,548	10,043,459	10,219,290
Atlantic....	*Nil*	43,483	19,018	*Nil*	*Nil*	44,370	....	....	(*b*)
Baltic......	17,724,854	17,817,836	17,549,762	15,370,449	13,373,961	7,736,124	7,001,945	12,028,947	(*b*)
Cal. & Hecla.	81,660,723	74,593,553	72,672,469	72,861,925	67,856,429	45,016,890	53,691,562	72,613,320	76,762,240
Centennial..	2,196,377	2,583,793	1,572,566	1,493,834	1,742,338	1,612,262	2,287,532	2,347,500	2,367,400
Champion..	17,786,763	18,005,071	19,224,124	15,639,426	17,225,508	12,080,592	15,807,206	33,407,599	54,747,498
Franklin ...	3,703,421	1,615,556	966,353	820,203	1,710,651	1,021,440	93,283	1,314,969	3,116,566
Isle Royale.	3,011,664	5,719,056	7,567,399	7,490,120	8,186,957	4,158,584	6,593,451	9,342,106	12,412,111
Mass.......	1,766,930	1,723,436	1,321,885	1,326,898	2,045,006	1,213,545	2,944,952	4,638,452	4,752,588
Michigan...	3,000,206	1,979,305	36,682	327,773	300,000	....	....	....	....
Mohawk....	10,295,881	11,248,474	11,412,066	12,091,056	11,995,598	5,778,235	11,094,859	15,882,914	13,834,034
Osceola.....	21,250,794	25,296,657	19,346,566	18,388,193	18,413,387	11,325,010	14,970,737	19,731,472	19,586,501
La Salle....	....	....	....	....	....	287,200	540,731	*a* 700,000	1,380,352
Quincy.....	20,600,361	22,511,984	22,517,014	22,252,943	20,634,800	12,184,128	15,356,380	22,045,813	21,065,612
Superior....	21,244	1,789,315	3,181,041	3,236,233	3,921,974	2,992,765	3,217,635	4,000,000	3,034,656
Tamarack..	12,806,127	13,533,207	11,063,606	7,494,077	7,908,746	4,168,743	1,074,808	3,888,150	6,606,620
Trimountain	6,034,908	5,282,404	5,694,868	6,120,417	6,980,713	4,990,938	5,048,306	8,302,896	(*b*)
White Pine.	....	....	....	....	....	....	....	....	4,207,449
Winona....	*Nil*	*Nil*	*Nil*	*Nil*	2,307,237	1,448,737	1,352,084	1,732,638	2,167,255
Wolverine..	9,555,233	9,971,482	10,469,253	9,630,639	9,408,960	1,550,000	3,435,459	*a* 7,400,000	....
Victoria....	1,290,040	1,164,564	1,164,564	1,303,331	1,224,911	4,488,000	1,486,242	1,499,695	1,661,832
Others.....	....	2,862,233	899,647	294,873	....	....	....	....	....
Totals ...	222,123,688	230,971,051	223,179,539	216,119,011	225,945,712	135,409,566	165,697,325	253,710,422	273,692,525

a Estimated as given in *Min. Sci. Press*, Jan. 8, 1916, p. 63.
b Included in Champion (Copper Range Co.).

DIVIDENDS PAID BY MICHIGAN MINES

Mine.	1914.	1915.	1916.	Mine.	1914.	1915.	1916.
Calumet & Hecla	$1,000,000	$5,000,000	$7,500,000	Quincy ...	$55,000	$880,000	....
Copper Range Con..........	....	1,182,003	3,941,648	Tamarack.	....	....	....
Mohawk........	100,000	600,000	1,700,000	Wolverine	240,000	....	....
Osceola.........	288,450	1,057,650	1,826,850	Totals....	$1,683,450	....	....

On July 15, 1916, the Calumet & Hecla Co. celebrated its 50th anniversary with a special holiday to its 5500 employees and by medals to its many employees of long service. As the most successful mining company of the United States and perhaps the first big success in copper mining, the company has been of very great benefit to the mining interests, while the policy to its employees has long been recognized as a model to follow.

The discovery of the lode was made Sept. 17, 1864 by Edwin J. Hurlburt; in December following, the Calumet Co. and Hecla Co. were organized, paying dividends in 1869 and 1870 respectively. The two companies were consolidated in 1871 with a capital of $1,000,000 in 40,000 shares, increased in 1879 to 100,000 shares of $25 each. The merged companies had already paid $2,800,000 in dividends.

In 1874 the output was 230,000 tons of ore that yielded 4.28 per cent. copper at a cost of $7.40 per ton. In 1916 the output was 76,545,021 lb. copper. In 1883 the stopes averaged 8 ft. wide and the ore 4.5 per cent. copper and the mine was 3000 ft. deep on the dip. At present the deepest shaft, the Red Jacket, is 4920 ft. vertical. During the 50 years of its existence the Calumet & Hecla Co. has paid $1339 a share dividends. In 1916, the mine output was 3,188,583 tons of ore yielding 76,545,021 lb. of copper.

In 1905 the company's charter was amended to permit it to organize and control subsidiary companies and the corporation now controls ten successful producing companies, whose dividends form a substantial addition to the earnings of the parent company.

In 1915 the Calumet & Hecla Co. received $866,766 in dividends from its subsidiaries. These subsidiary companies produced as much copper in 1916 as the parent company.

"At the Calumet & Hecla the cost of milling and smelting is relatively low, being not to exceed 2 cts. per lb. At several of the copper mills in Michigan, the cost of milling is as low as 1 ct. per lb. on the finished metal. The cost of smelting is perhaps 0.5 ct. per lb. Any close analysis of the operations of the Calumet & Hecla is difficult because the costs on the conglomerate ore, which contributes two-thirds of the mine's output, are higher than those for the amygdaloid ore, which, however, contains less copper per ton. During 1915, the Calumet & Hecla treated 1,739,984 tons of ore from its famous conglomerate lode, about 55 per cent. of the total tonnage milled, and 1,448,599 tons from the Osceola amygdaloid lode, constituting the remaining 45 per cent. The conglomerate ore was more than twice as rich as the amygdaloid ore, yielding 29.74 lb. of copper per ton to 13.32 lb. per ton of the amygdaloid. But the conglomerate ore is both more expensive to mine and the amount in reserve is not large. It is used to sweeten the low-grade amygdaloid. The higher costs on conglomerate are due to the greater depth of underground workings, the consequent heat at that depth, the expense of timbering a loose hanging wall, and the tough angular character of native-copper conglomerate which makes drilling, shoveling, and stamping more expensive. Taking the figures for last year, the mine cost per ton of conglomerate (excluding construction) was $2.13 per ton. For an average of 29.74 lb. of copper per ton, this means over 7 cts. per lb. on the metal produced as the charge for mining. The total cost of producing copper from conglomerate ore in 1915 is given at 8.69 cts. The difference between 7 and 8.69 cts. or 1.69 cts. must pay for construction, the cost of which is always high at these mines, for smelting and refining, freight, selling, and all miscellaneous expense. Considering the amygdaloid ore, which in 1915 averaged

13.32 lb. per ton, and for which the mine cost per ton of ore (excluding construction) was $1.07, this shows a cost of over 8 cts. per lb. of metal to be charged against mining. The total cost of producing copper from amygdaloid ore was 9.71 cts. per lb., leaving only 1.71 cts. per lb. for all other expense. It is evident that the problem at Michigan copper mines is largely one of cheap mining. The milling and smelting are comparatively simple, the freight rate to the Eastern market is low by reason of lake transportation, and the selling cost of such an established brand of copper, so much in demand, is small. It is apparent why the management decided a few years ago to conduct a vigorous campaign to lower the underground cost of mining."[1]

The loss of the Trimountain mill by fire was offset by increased stamps at the Ahmeek, but every mill in the district, save the Adventure, has been operated and mine production at the end of 1916 was limited by mill capacity. Owing to the necessity of crowding production to meet the insistent demands of cartridge makers for Lake Superior copper, it was not a period of new exploration, or improvement of processes by the companies, though some exploration work was done in the region about the White Pine mine and at the Old Norwich mine by the Cass Mining Co. The year was notable for the absence of new flotations, which is the more remarkable considering the high price of copper and the great profits realized by the operating companies.

The Mohawk company reports a decreased production in 1916, due to labor shortage. The output was 13,834,034 lb. copper, compared with 15,882,914 lb. in 1915. The mine yielded 664,547 tons, yielding 20.82 lb. copper per ton, the highest return of recent years. Mining costs were 7.35 cts. per lb. and smelting 1.17 cts.; construction, etc., 0.33 cts., a total of 8.85 cts. per lb., contrasted with 7.48 cts. in 1915. The average price realized was 25.28 cts. per lb. and the total receipts were $3,496,860, giving a yearly surplus of $570,054 after paying $1,700,000 in dividends, the total surplus being $2,333,839. Earnings for 1916 equal $22.75 per share and dividends $17 per share.

Winona produced 2,167,255 lb. copper from 161,828 tons of ore, or 13.39 lb. per ton, as against 16.79 in 1915 and 10.96 in 1914. The balance of assets on Dec. 31, 1916, was $33,045, compared with $223,324 in 1915 and $92,648 in 1914.

Copper Range earnings for 1916 were about $10 per share, including $2.40 per share from its half ownership of the Champion mine. The Trimountain Co. having been ordered dissolved and the Baltic wound up, the Copper Range is now practically an operating, rather than a holding company.

[1] *Min. Sci. Press*, Sept. 9, 1916.

Montana.—The production of 352,928,373 lb. of copper in 1916 is an increase of nearly 90 million pounds over the 1915 record of 267,231,014 lb. In value this increase is 108 per cent., the 1916 output representing $97,461,000. The copper industry of the State is practically that of Butte, whose mammoth operations dwarf the operations of the few small outside producers. All the Butte mines operated to capacity in 1916 and several small properties, formerly unprofitable, resumed operations.

The operations of the Anaconda Copper Co. produced 336,900,000 lb. of copper compared with 254,311,574 lb. in 1915.

The company's own mines produced 312,900,000 lb. of copper, this being the largest output of any one copper company in the world. The Anaconda Copper Co. is not only a copper producer, but in 1916 was successfully started as a large zinc producer. The completion of a large electrolytic zinc plant at Great Falls enables the company to reduce the zinc ores, so abundant in 4 of the 26 Butte mines.

The East Butte Co. paid off its entire bonded indebtedness early in the year and made important additions to its concentrating plant. The company continued ore extraction and development on its properties without appreciable change in reserves. The monthly production is about 1,500,000 lb. of copper.

The North Butte Co. continued operations at its Speculator and Granite Mountain shafts, producing 21,505,584 lb. of copper at 23.29 cts. per lb., and 412,953 lb. of zinc. The mines are, it is currently reported, declining in both the amount and value of ore reserves, but the East Side properties of the company, on the footslopes of the continental divide ridge, east of Butte, are confidently expected to develop orebodies to replace those worked out on the Butte hill. This expectation has been greatly strengthened by the development work on the Sinbad mine of the Butte Main Range property, controlled by the Tuolumne Co.

The Butte-Alex Scott property was purchased by the Anaconda Copper Co.; the Butte & Ballaklava continued operations on a modest scale and there was no general revival of prospecting work on the outlying properties of Butte such as characterized so many other mining districts of the country in 1916. The only new work done was by the Butte & Bacorn Co., which started exploration work near the end of the year. The Butte & Zenith City unwatered their shaft, near Silver Bow Junction, and did extensive crosscutting, disclosing strong veins with scattered copper values, but as yet no commercial ore.

The most notable new development outside of the Anaconda properties was at the Sinbad mine, in the foothills east of the Leonard mine, where the Tuolumne Co. re-opened the property of the Butte-Main Range Co. and by crosscutting on the 700-ft. level, disclosed an ore zone 120 ft.

wide with two workable veins, the east one having a stoping width of 10 to 25 ft. and carrying 3 to 5 per cent. copper with good silver values.

The Bullwhacker mine was reopened and development proved the ore-body to have a much greater size than previously supposed. Shipments were made to Greenwood, B. C., but the siliceous character of the ore made it difficult for the owners to find a market for it. The mine is now controlled by the same interests that took over the Butte-Duluth property which was re-opened and worked in the latter part of 1916, under the direction of Alfred Frank, using scrap-iron precipitation for the copper solution instead of the more costly electrolytic method.

Davis Daly has at last become a profitable producer and has also had a small output of zinc ore. Production for 1916 was 20,511 tons of 4.04 per cent. copper, mostly from the 2500-ft. level; the mining cost was $7.22 per ton. Early in 1917, ore was developed on the 2400-ft. level and shipments averaged 200 tons per day or 1,126,921 lb. of copper and 68,830 oz. of silver for the first 3 months of 1917.

New Mexico.—The copper output of New Mexico for 1916 was 76,955,335 lb.[1] as compared with 75,515,130 lb. in 1915. Over 90 per cent. of this ore comes from the Chino Copper Co.'s operations at Santa Rita, though the Burro Mountain Copper Co. started operations in April, treating their ore in a new 1200-ton concentration mill at Tyrone, which has run at full capacity since June.

At Fierro, a 400-ton mill, erected by the Hanover Bessemer Iron & Copper Co., also yields some copper ore.

The Santa Fe Gold & Copper Co., operating a 125-ton matting plant at San Pedro and the 85 Mining Co. near Lordsburg, are the only other producers of any magnitude.

The Chino Copper Co.'s operations in 1916 yielded 75,644,436 lb. copper, compared with 64,887,788 in 1915. The average copper content was 1.83 per cent., varying from 1.87 per cent. in the first quarter of the year to 1.79 per cent. for the second, 1.89 per cent. in the third, and 1.78 per cent. in the fourth quarter. The recovery improved during the year from 22.77 lb. per ton of ore milled in the first 3 months of the year to 26.05 in the last quarter, despite the fact that the ore was slightly low-grade and the mill crowded beyond its rated capacity, production being almost 7,000,000 lb. monthly for the last quarter compared with a little over 5,000,000 per month for the first part of the year. Costs rose slightly, increasing from 8.17 cts. per lb. for the third quarter to 8.89 for the final months of the year. The mill handled 8587 tons daily in the last period.

In the Lordsburg district, the active properties during 1916 include

[1] *Eng. Min. Jour.*, Jan. 6, 1917.

the Octo, Bonney, Nellie Gray, Nellie Bly, Waldo-Beam and 85 Mining companies. The latter company installed another 450-hp. oil engine. The new companies organized include the 85 Extension, and the Western Mining & Development Co., owning the Bonney mine.

In the Carocito district, 50 miles southeast of Albuquerque, a number of prospects have shipped ores from Schälle station on the Sante Fe. The oxidized ores occur in bedded deposits of limey shale averaging but 10 in. in thickness, six beds occuring in a thickness of 100 ft. and dipping gently away from the mountains. The one copper outcrop is observable along a line of cliffs for 10 miles. Shipments of hand-sorted ore carry 6 to 9 per cent. copper.

Nevada.—The State yielded 100,816,724 lb. of copper in 1916, valued at $28,120,000, compared with 68,636,370 lb. in 1915. The greatest producer is the Nevada Consolidated Copper Co. at Ely.

Although operations in the Yerington district, Lyon County, were seriously curtailed by the continual inactivity of the smelter at Thompson, several properties continued development work, shipping ores to the ore-buying works at Hazen.

The Nevada Douglas Co. continued operations, but its 250-ton leaching plant has not as yet proven as successful as expected, though operated for a part of the year.

Ore from the Montana Nevada mine was treated in a 10-ton leaching plant. The output of many small mines in the Santa Fe and Silver Star districts of Mineral County, and near Luning and Mina, aggregate some 1500 tons a month and the mines of the Bullion district near Elko have been steady producers, being operated by various sets of lessees.

The Nevada Consolidated Copper Co. reports show that the company's operations were the largest in its history. Production for the year was 90,409,606 lb., an increase of 27,682,955 lb. over the 1915 production. Production for the latter half of 1916 was at the rate of 4,000,000 tons of ore annually, carrying 1.65 per cent. copper. Of this amount about 80 per cent. is mined by open-cut steam-shovel work and 20 per cent. by underground methods. The cost of copper produced including smelter plant depreciation and all charges save ore extinguishment, and after crediting all miscellaneous earnings, was 8.51 cts. for the second quarter, 8.67 cts. for the third quarter and 9.32 cts. for the fourth quarter of the year. Excluding depreciation the costs are less than 8 cts. per lb. The total balance of earned surplus at the end of the year was $12,353,643.

The Consolidated Coppermines Co., which now controls the old Giroux Consolidated Mines Co., the Butte & Ely Copper Co., the New Ely Central Copper Co., the old Coppermines Co. and the Chainman

Consolidated Copper Co., has produced a moderate tonnage of steam-shovel ore, mined and treated by the Nevada Consolidated Copper Co. During the last 6 months of 1916, the output was 28,120 tons.

Oregon.—The copper production of Oregon is but small, that of 1916 being estimated at 1,000,000 lb., compared with 797,471 lb. in 1915. This ore comes mostly from the Waldo district, near Takilma, in the southern part of the State.

The Queen of Bronze mine, 1½ miles east of Takilma, owned by Twohy Bros. of Portland, yields chalcopyrite-pyrrhotite ore found in greenstone near contacts.

The Waldo mine nearby has a deposit of chalcopyrite-pyrite ore in quartz porphyry near a slate contact. The property is being equipped with a 50-ton mill to handle the lower-grade ore on the dump and in reserve.

The combined output of these two mines is about 450 tons a month of 10 per cent. ore which is hauled 27 miles to the railroad and shipped to the Tacoma smelter.

The Copper Queen mine, 3 miles southeast of Leland on the Southern Pacific Railroad, is developing. The Almeda, 3½ miles north of Galice, has a small furnace, run intermittently during 1916, producing a 30 to 40 per cent. matte, hauled 18 miles to the Southern Pacific Railroad and shipped to Tacoma. The Copper Eagle mine, 4 miles northwest of Galice, is developing a chalcopyrite vein opened by a drift for 400 ft.

In Josephine and Jackson Counties, there are several small copper properties under development, the most important being the Copper King mine on Slate Creek, 18 miles east of Leland station, owned by the United Copper Co. The mine shows a 4- to 6-ft. vein of 4 to 5 per cent. ore. A mill is under construction.

The Iron Dyke mine, near Homestead, continued shipping ore throughout the year.

Tennessee.—The production of this State for 1916 was reduced to 14,556,278 lb., compared with 18,205,308 lb. in 1915 and 18,661,112 lb. in 1914. This output was all from the two operating companies, the Tennessee Copper and the Ducktown Copper, Sulphur & Iron Co.

The Tennessee Co. has passed through a strenuous year, with a re-organization of its affairs as a result of its inability to fulfill contracts made for acid and more especially one with the Russian Government for 4,800,000 lb. of trinitrotoluol before Nov. 1, 1916. The government advanced the company $1,140,000, or 25 per cent. of the purchase price. The company built a plant which was burned down before it went into commission and suits are now pending against the company for the recovery of this money. Owing to financial and technical difficulties, the copper production of the company actually declined and in November, 1916, the Tennessee Copper & Chemical Corporation was organized by Adolph Lewisohn and J. S. Bache & Co. to re-finance and restore the company to its former prosperous condition. This company now owns 95 per cent. of the stock of the old company.

The production for 1916 was 9,402,295 lb. of copper, with 55,790 oz. silver and 219 oz. gold. The company treated 806,243 tons of custom ore. The cost of producing copper was 14.36 cts. per lb. The sulphuric acid output for the year was 181,637 tons. The operations for the year were disturbed by numerous troubles, including a serious cave-in at the mine, a strike and other labor troubles and the development of troubles in the No. 1 acid plant which necessitated a practical re-construction of that plant.

The Chattanooga Copper Co. developed copper ore in several drill holes and was re-organized as the Ocoee Copper Co.

Utah.—The State produced 242,000,000 lb. of copper in 1916, an increase of 30 per cent. over the 1915 figures. As usual, the major part of this output came from the Utah Copper Co., the giant of the copper mines of the world, whose average daily output for 1916 was 31,000 tons, reaching 40,000 a day at times and keeping two railways busy hauling over 600 cars of ore a day. The Utah Copper Co.'s production was 196,752,631 lb. of copper, compared with 156,207,376 lb. in 1915.

The Utah Consolidated produced 1,000,000 lb. monthly and the Ohio, Yampa, Utah Apex and Utah Metal companies were also notable producers of the Bingham district.

The Utah Copper Co. mined 11,347,400 tons of ore in 1916 that averaged 1.433 per cent., 1.3810 per cent., 1.4484 per cent. and 1.4742 per cent. copper for each quarter of the year respectively. The extraction varied between 64.27 and 60.44 per cent., decreasing slightly as the plants were operated at nearly twice their normal capacity and the ore contained some carbonates. The costs varied from 7.19 cts. per lb. of copper for the first quarter of the year, to 6.322 for the third quarter, decreasing as the output was increased. The cost for the last quarter of 1916 rose to 7.498 cts. per lb., owing to unusually severe weather conditions, with consequent decrease of tonnage and partly to an increased wage scale and cost of supplies.

A notable feature of Utah Copper Co.'s operations for the year is the construction, not yet completed, of a leaching plant to handle 2000 to 4000 tons daily of the oxidized ore which has hitherto been removed as overburden and stacked.

The leaching plant will have a crushing plant, a series of leaching tanks, a pumping plant for solutions, sulphuric acid storage tanks and a precipitation plant. The ore crushed to ½-in. will go to 12 concrete tanks built in two sections, each with six compartments. Each compartment is to be 50 by 100 by 18 ft. deep, lined with asphaltic mastic, with lumber racks and cocoa mattings on the bottom. Each compartment will hold 4000 tons of ore and 290,000 gal. of solution when ore is covered to a depth of 6 in. From the tanks the solution will run to a Dorr thickener and then overflow to launders, with scrap iron for precipitation of the copper.

The Utah Consolidated reports net ore sales of $4,359,724 and ended 1916 with a balance of $1,924,177, or net surplus of $738,427, after paying $1,125,000 dividends.

The Yampa mine was re-opened during the year and furnished 200 tons of ore daily, largely from new ore-bodies opened on the 1600-ft. level. The Bingham Coalition Mines Co., organized by Boston interests, acquired the Butler, Liberal, North Utah and Massasoit group. The Montana Bingham, Congor, Bingham mines, Silver Shield, etc., were all operated.

The Ohio Copper mine, operated for several years by Alfred Frank under lease, was sold to satisfy the bondholders of the Ohio Copper Co., in August, 1916, but was redeemed by the stockholders who re-organized as the Ohio Copper Co. of Utah and resumed operations at the property with Alfred Frank as manager, at the end of the year. The mine was operated in 1916 by the General Leasing Co., mining and milling 2240 tons of ore daily that carried 21 lb. copper per ton. The copper sulphide occurs in tiny particles, finely disseminated throughout hard quartzite, so that water concentration is wasteful, recovery being but 11 lb. per ton. Mining costs were 22 cts. per ton and transportation charges through the Mascotte tunnel to the mill at Lark were 16 cts. per ton. Copper production averaged 725,000 lb. per month, with operating profits of 27 cts. per ton, or about $101,000 a month. A royalty of about $15,000 a month was paid to the Ohio Co., the royalty being on a sliding scale, 10 per cent. on 16-ct. copper and 2 per cent. additional for each 1-ct. increase in price.

The mill is to be equipped with Mineral Separation flotation machines, which are expected to increase the saving to 80 per cent. The new company starts out with $300,000 cash and 500,000 shares in the treasury.

Throughout the other districts of the State, there was a great revival of mining development work and the number of producing mines of all kinds increased from 231 in 1915 to 261 in 1916. All the lesser camps, Tintic, Park City, Beaver county, Stockton, Ophir, Big Cottonwood, Alta and American Fork, were active. At Newhouse, the 650-ton plant of the Utah Leasing Co. operated on the old Cactus mine tailings dump.

At Tintic there were 52 producing mines, 11 of them dividend payers, although copper ores form but a part of the output of this camp. The Eagle & Blue Bell continued its shaft to water-level and opened up and developed large ore-bodies. The Chief Consolidated was the heaviest shipper in the camp, marketing gold-silver, lead, copper and zinc ores. This company took up large holdings on the north and east sides of the Tintic district, sunk its Homansville shaft 600 ft. and did much other development work. The company acquired control of the Plutus.

The Colorado and Beck Tunnel were merged into the Colorado Consolidated Mines Co. Development work was started at depth on the Colorado-Sioux-Iron Blossom ore channel, and a body of copper ore of good size was opened in the Iron Blossom. The Dragon Consolidated, Mammoth, Centennial-Eureka, Gemini and Grand Central were heavy producers.

Vermont.—An interesting event of the year was the re-opening of the old Ely copper mine, over 2500 ft. deep, controlled in recent years by the Westinghouse interests and now owned by the Vermont Copper Co., in which August Heckscher and associates are interested.

Washington.—The State produced 2,473,481 lb. of copper in 1916, doubling the 1915 output of 903,661 lb. The most important copper district in the State is near Chewelah, which yielded about 10,000 tons of ore in 1916, mostly from the United Copper mine.

The Copper King, Blue Star, June-Echo, and Amazon mines were small producers.

The Napoleon mine near Marcus produced very low-grade ore, valuable for fluxing, during the year and the Laurier mine in Ferry County also added to the State's output.

The Loon Lake district in Stevens County produced a small tonnage throughout most of the year. The Index district, on the west side of the Coast range, has many small mines, still inactive, and the Dutch Miller remained idle for lack of transportation for its high-grade ore.

Copper Mining in Foreign Countries

The copper production of foreign countries for 1916 was materially affected by the World War and only estimates are available for the amounts mined in the various European countries. It is reasonable to suppose, however, that the warring nations have maintained, if they have not increased, production.

Africa.—Estimates of the total output of copper from the widely scattered mines of the continent of Africa, show a 1916 production of 50,000 metric tons, compared with 27,000 metric tons in 1915.

AFRICAN COPPER PRODUCTION. (Long Tons)

	1911.	1912.	1913.	1914.	1915.
Katanga	1,100	2,345	6,790	10,700	......
Cape Colony	4,480	3,870	3,220	2,420	......
Namaqua	2,500	2,500	2,500	2,250	......
Sundries	9,000	7,655	10,000	2,820	......
Total	17,080	16,370	22,510	23,650	27,000

The largest source of supply is the Katanga district, jointly controlled by the Tanganyika Concessions, Ltd., and the Belgian Government, operating as the Union Minière du Haut Katanga.

The copper output of this company has increased from 997 tons in 1911 to 2492 in 1912; 7407 in 1913; 10,722 in 1914; and 14,190 tons in 1915, to a total of 25,000 tons in 1916.

During the year the costs were considerably reduced by the use of new furnaces. This saving offset the increased cost of shipping and supplies. The profit for 1916 is given at over £2,000,000. Because one-fifth of the ore reserves—estimated at 6,000,000 tons—average 15 per cent. and the balance 7 per cent., the utilization of the lower-grade ore has been the company's chief problem. As the result of elaborate and extensive tests carried on in the experimental plant of the company during 1915 and 1916, it is now officially stated that these lower-grade ores can be successfully and profitably handled, either by concentration and smelting, or by leaching. The leaching process is particularly applicable if the 60,000-hp. hydro-electric plant, which is planned, is built. The geology of this interesting deposit is described by H. Foster Bain in a recent article.[1]

The Haenertsburg Gold & Copper Co. is equipping an old property, a reef mine, whose ore contains 1 to 3 per cent. copper. The ten-stamp mill supplemented by a tube mill and concentration plant, was run in an experimental way in the summer of 1916.

At the Falcon mine, Umvuma, Rhodesia, a copper smelting and converting plant is in operation and solicits custom ore.

The Cape Copper Co. reports that the returns of copper from its mines in Cape Colony have been less and the costs of production greater, on account of the war. The returns from the O'okiep mine for the fiscal year ending Aug. 31, 1916, were 13,496 tons of 11.22 per cent. ore, compared with 13,345 tons of 10.88 per cent. in 1915. The reserves have been maintained at 6000 tons, computed on a basis of 20 per cent. copper, but there are, in addition, about 120,000 tons of 4 per cent. ore.

At the Nababeep South mine, the output was 70,677 tons of 3.7 per cent. ore as compared with 68,141 tons of 4.35 per cent. ore in 1915. Reserves are stated to be 120,000 tons of 4.5 per cent. ore, a decline of 40,000 tons during the year.

[1] *Min. Mag.*, Feb., 1917.

The Nababeep North mine yielded but 1326 tons of 4.96 per cent. ore, mostly from the capping. The Narrap mine was closed down in September to enable the management to make various changes needed to reduce costs. The production of this mine for the year ended Aug. 31, 1916, was 4494 tons of 5.37 per cent. copper ore.

The Rakkha Hills mines are not yet productive, though the blast-furnace plant was approaching completion in the autumn of 1916. The mine output will average 300 tons of 4 per cent. ore per day when operations begin. The reserves at this property are estimated at 294,030 tons of developed ore and 50,961 tons of partly developed, a total of 345,000 tons that will average a trifle over 4 per cent. copper.

The Messina (Transvaal) Development Co. was formed in 1905 by A. M. Grenfell to acquire a copper property in northern Transvaal. On Mr. Grenfell's bankruptcy 2 years ago, the control changed hands and H. C. Hoover joined the board. The mine was re-sampled by A. F. Kuehn, and the report for the year ended June 30, 1916, shows that 111,909 dry long tons of ore averaging 5.4 per cent. copper was raised, out of which 894 tons averaging 45.3 per cent. copper was removed by hand-picking. The remainder, together with 6888 tons of old sand and slime averaging 5 per cent. was sent to the concentrator, where 11,056 tons of shipping concentrate averaging 42.9 per cent. and 5251 tons of smelting concentrate averaging 18.1 per cent. were produced. At the furnace, 1737 tons of matte was produced averaging 56.9 per cent. copper. The hand-picked ore, the high-grade concentrate, and the matte were sold for £559,202. The profit was £268,721, out of which £15,000 was paid as debenture interest, £42,600 was paid as taxes, and £140,000 was put on one side for excess profits tax. The shareholders received £36,357, or 5 per cent., this being the first dividend ever paid. The large appropriation for excess profits tax is explained by the fact that the earning of profits has only just begun. The ore raised during the year averaged 5.4 per cent. copper as already mentioned; the year before, the average content was 7.3 per cent. The reserve of practically proved ore is estimated at 151,409 tons averaging 5.23 per cent., as compared with 131,700 tons averaging 6.63 per cent. the year before. The possible ore is estimated at 56,652 tons averaging 3.43 per cent., as compared with 43,700 tons averaging 3.74 per cent. Geological examinations recently made are encouraging for further development in depth and also laterally. H. C. Hoover has resigned from the board and J. A. Agnew has been elected in his place.

The ore occurs in short, disconnected bunches in a series of veins, in which the ore is of good value, the New Gringo shoot of the Bonanza vein system being 35 ft. wide with an average copper content of 13 per cent. for the first 15½ ft. of ore. This shoot was cut in 1916 on the 6th, 7th and 8th levels. As a rule the ore is narrower. The No. 5 shaft, the deepest working, has reached a depth of 1736 ft.

The concentration mill handled 111,909 tons with a 91 per cent. recovery in the year ending June 30, 1916.

The Bwana M'Kubwa copper mine, owned by the Rhodesia Copper & General Extension Co., was re-opened in April, 1916, to treat an oxidized ore averaging 10 per cent. copper. The resultant concentrate averages 40 per cent. copper. Under normal conditions the plant produces 200 tons of concentrate per month and at this rate the reserve is sufficient for a year. The lower-grade ore, averaging 4 to 5 per cent. of which there is 3 million tons above the 350-ft. level, will be treated by an electrolytic leaching process which is estimated to yield a profit of 10s. per ton of ore. The first unit of this plant will have a capacity of only 100 tons per day, but it will be enlarged to 500 tons. Owing to the greatly increased prices of machinery and supplies, the company's funds were insufficient to finance this plant in 1916 and negotiations are pending among the leading shareholders for raising further funds.

The best-known copper deposits of German Africa are in the Otavi district, at Tsumeb. Others are found at Otijsongati, near Windhuk, at Khan, Husab, and also in the districts of Swakopmund and at Sinclair to the northeast of the Luederitzbucht district. At Tsumeb, the minerals occur in a compact dolomite; the most abundant mineral is galena, but chalcocite, enargite and famatinite occur. By oxidation these have changed to a number of unusual mineral species, including one named after this locality. The areas carry about 10 per cent. copper, 50 per cent. lead, ½ to 2 per cent. antimony, 1 to 2 per cent. arsenic, with traces of gold and some silver.

The other copper deposits of the protectorate are mostly found in pre-Cambrian rocks and are of a different type. The most important are those of Otijsongati, where lenticular veins cut pre-Cambrian gneiss. The copper occurs in oxidized minerals, associated with limonite. At the Sinclair deposits quartz veins cut through gneiss and schist and carry copper ore in shoots. Similar cupriferous quartz veins occur at Meuras, to the southwest of Rehobeth, and at Spitzkopf, to the northwest of Rehobeth.

At Gaidip on the Orange River, to the east of Ramasdrift, copper ore occurs in veins 2 m. thick, near a quartz diorite intrusion. The ores carry chalcopyrite and bornite with associated pyrite in a quartz gangue.

The mineral deposits of the Khan valley closely resemble those of Swakopmund. At this place a vein 6½ ft. thick is mined and concentration works installed, the ore carrying 7½ per cent. copper. In other parts of Damaraland, copper deposits are found as impregnations of mica schist, notably at Gorap. Similar deposits in mica schist are found at the Matchless mine to the southwest of Windhuk.[1]

Australasia.—The combined copper production of the Australasian States for 1916 was about 35,000 metric tons, compared with 32,512 tons in 1915. The Australian production of copper and also of lead and zinc was formerly controlled by Aaron Hirsch and other German interests, which in fact dominated the metal output of the world until 1914. This direction has been completely destroyed in Australia by the war, but since the industry has not yet been reorganized on broad lines, the production for 1916 is less than the refining capacity of existing plants. The failure to crowd production to meet the unheard-of prices for the metal is largely due, no doubt, to the war profits taxation. In fact, the Australian copper industry is at present in an unsatisfactory condition; having in the past been granted governmental aid in different phases of the industry, the industry lags because this is withdrawn. Moreover, no governmental efforts are made to stimulate new discoveries, no branch railways are under construction to mines imperatively needing cheaper transportation, and labor is scarce, largely because of the great number of men employed on government work.

The total amount of about 35,000 tons of refined copper shipped in 1916 was produced as follows:

	Tons.
Queensland	17,500
South Australia	7,500
Tasmania	7,000
New South Wales	2,000
West Australia and Papua	1,000
	35,000

New South Wales suffered from the reduced output and financial difficulties of the Great Cobar mine, the one large producer. As a result the State's former production of 9000 to 10,000 tons a year has fallen to about 2000 tons. With abundant copper ores and a wealth of deposits, this, the oldest industry of the Commonwealth, is sadly decadent and properties already proven are idle for lack of railway facilities.

The policy of encouraging the treatment in Australia of all copper ores produced within the Commonwealth has been energetically pushed, and considerable extensions of the treatment works at Port Kembla and Wallaroo have been made. Before the end of the year it is expected that all copper ores and products will be refined in the Commonwealth. The Port Kembla Co. is now practically a coöperative establishment. Its capacity has been materially increased, and shortly will be in the position of refining electrolytically all the auriferous and argentiferous

[1] *L'Echo des Mines*, Sept. 24, 1916.

PRODUCTION OF COPPER IN AUSTRALASIA
(In tons of 2240 lb.)

Year.	New South Wales. Ingots, Matte and Regulus. Tons.	New South Wales. Ingots, Matte and Regulus. Value.	New South Wales. Ore. Tons.	New South Wales. Ore. Value.	Queensland. Copper, Tons.	Queensland. Value.	South Australia. Copper, Tons. (a)	South Australia. Value.	Tasmania. Blister Copper. Tons.	Tasmania. Blister Copper. Value.	Tasmania. Copper Ore. Tons.	Tasmania. Copper Ore. Value.	Western Australia. Copper Ore, Tons.	Western Australia. Copper Tons. (b)	Western Australia. Combined Value.
1909	6,857	£423,642	109	£1,095	14,494	£853,196	5,697	£334,584	8,638	£586,419	1,588	£21,619	6,959	833	£104,644
1910	8,435	450,491	4,455	35,766	16,387	932,489	5,102	306,120	8,193	553,822	671	13,150	6,309	1,281	95,928
1911	10,618	578,198	1,482	11,904	20,384	1,151,351	5,922	332,500	6,022	385,797	2,286	22,852	9,825	829	78,364
1912	8,990	560,025	2,044	19,766	23,120	1,698,280	6,295	461,500	5,136	430,965	1,392	9,479	13,607	1,703	120,158
1913	9,153	595,826	308	2,907	23,655	1,660,178	7,161	488,986	4,569	364,332	1,967	10,932	(c)4,339	(c) 82	145,513
1914	3,500	274,671	3	11	18,436	1,118,648	6,881	417,487	7,509	477,361	3,288	18,680	(c)3,913	(c)183	38,174
1915	6,973	....	*Nil*	*Nil*	19,704	1,428,793	7,725	561,247	7,901	709,167	66	367	737	946	91,169
1916	6,171	....	*Nil*	*Nil*	19,520	2,265,422	7,279	....	6,305	884,689	97	1,765	....	....	....

(*a*) Small amounts of copper ore and sulphate not included here. (*b*) Ingots and matte. (*c*) Exports.

blister copper produced in Australia. It has also since the outbreak of war installed a copper "fire" refinery. The capital costs of works and metals in the course of treatment under normal conditions represent not less than £500,000. A new company, called "Metals Manufactures, Limited," has been formed, with a capital of £200,000, for the production of copper and brass wire, cables, tubes, plates, alloys, etc. These works are in the course of erection at Port Kembla, and when completed will be in the position of meeting all Australian requirements.[1]

The principal copper mines of New South Wales are the Great Cobar, Mouramba, C.S.A., Mt. Hope, and Abercrombie.

The Great Cobar was worked during 1916, producing about 650 tons daily. The output for 1916 was about 2600 tons of copper. The Mouramba Co. of Nymagee, also in the Cobar district, has taken over the old Nymagee N.G.E. smeltery at Eskbank and is remodeling and enlarging the plant. In 1916 the company smelted 18,500 tons of ore and produced 663 tons of copper. The mine is handicapped by its location 45 miles from the railway.

The C.S.A. mine is being reopened and a smelting campaign is planned. A government engineer recently estimated that the property contains 150,000 tons of secondarily enriched ores, averaging 7 per cent. copper, available for smelting.

The Mt. Hope mine is situated

[1] *Min. Jour.*, Oct. 21, 1916.

11 miles from the railway line under construction to Broken Hill via Condobolin. Pending the construction of this line, the old dumps are being leased, there being 30,000 tons of tailings averaging 3 per cent. copper available for treatment.

The Abercrombie is a new London company, formed to take over the Lloyd copper mine at Burraga, which has been idle since July, 1914. The ore reserves of this mine estimated June 30, 1913, were 116,400 tons averaging 4.4 per cent. copper.

The Grafton mine at Cangai was operated in 1916 in a small way, yielding 161 tons of matte.

The latest official figures obtainable for New South Wales are for 1915, for which year the copper output was valued at £234,437, a decrease of £40,234 lb. from that of 1914, and the smallest production since 1896.

The Queensland production of 17,500 tons, or half the output of Australia, came largely from the operations of two companies, the Mt. Morgan and Hampden Cloncurry, whose united production for 1916 was about 15,000 tons. The first-named company was for a long period one of the world's greatest gold mines and now has a very profitable career assured as a producer of sulphide ores of copper.

The Mt. Morgan output for the year ending Nov. 26, 1916, was 8550 tons of copper, produced for £49 8d. per ton, sold at an average price of £99 12s. 4d.

The Mt. Elliott group is as yet of trifling importance as a producer, but the copper smelter refining works at Bowen will be completed in 1917 and will produce 700 tons of metal monthly.

The Hampden Conclurry Copper Mines was formed in Melbourne by the Baillieu group in the year 1906 to acquire the Hampden and Duchess copper properties, in the Conclurry district of North Queensland. More recently the Trekelano, Pindora, MacGregor, and other properties have been purchased. Smelting was started in 1911, and at first the matte was sent to the Mount Elliott smelter. The company's plant was extended in 1912, and the blister copper produced was sold to Germany. On the outbreak of war the operations were suspended, but by the financial aid of the Commonwealth Bank of Australia, work was re-started in a few weeks. The report for the half year ended Feb. 29, 1916, shows that 43,422 tons of ore was raised, coming from individual mines as follows: Hampden 8037 tons, Duchess 15,998 tons, MacGregor and Wallaroo 6374 tons, Answer 567 tons, and Salmon 12,446 tons. The smelter treated 48,360 tons, and, after refining, the yield was 3850 tons of copper, 957 oz. gold, and 31,110 oz. silver. The net profit was £141,973, of which £70,000 was paid as dividend, being 4s. per £1 share; £12,006 was written off for depreciation, £27,312 placed to equalization reserve, and £30,000 placed to general taxation.[1]

South Australia's production comes mainly from the old Wallaroo and Moonta properties, which in 1916 produced all but 500 tons of the State's entire output. The 1915 operations of the company produced 187,500 tons of ore, milling 175,590 tons that assayed 3.07 to 3.3 per cent. copper. Sulphuric acid and bluestone are produced. It is said the company considers exploration of the Karkarilla group.

Tasmania has but one producer, the Mt. Lyell, where concentration will ensure future prosperity for a property long known for its technical leadership. The report for the half year ended Sept. 30 last shows that 166,497 tons of ore was mined, as compared with 168,393 tons during the previous half year; of this ore, 84,292 tons came from underground and 18,519 tons from the open-cut, at Mount Lyell, while 57,130 tons came from the North Lyell, and 6488 tons from the Lyell Comstock. The following was delivered to the smelters: ore from Mount Lyell 95,784 tons averaging 0.48 per cent. copper, 0.8 dwt. gold, and 1.39 oz. silver; ore from North Lyell 55,057 tons averaging 5.98 per cent. copper, 0.1 dwt. gold, and 0.32 oz. silver; and concentrate from Lyell Comstock 2132 tons averaging 9.84 per cent. copper, 1.32 dwt. gold, and 0.66 oz. of silver. The yield of blister copper was 3173 tons, containing 3139 tons of copper, 4183 oz. of gold, and 170,399 oz. of silver. The flotation plant started on Feb. 17 on Lyell Comstock ore, and it has also treated low-grade ore from the North Lyell mine. In addition to ore sent to the smelter, 7027 tons of Mount Lyell ore was sent to the chemical works for the manufacture of sulphuric acid used in making superphosphate. Development was restricted owing to shortness of labor, but such work as was done continued to open up ore satisfactorily. The reserve on Sept. 30 was estimated at 1,726,485 tons at Mount Lyell averaging 0.53 per cent. copper, 0.8 dwt. gold, and 1.96 oz. silver; and 1,083,211 tons at North Lyell averaging 6 per cent. copper, 0.1 dwt. gold, and 1.33 oz. silver. The accounts show a profit of £242,962, out of which £102,712 has been reserved for taxes, though the actual amount payable as profits tax is not yet fixed. The company has invested £20,000 in Metal Manufactures Limited, a company which will erect works adjoining the electrolytic refinery at Port Kembla for the purpose of establishing a copper manufacturing industry for Australia.

Western Australia, which has a great number of attractive copper prospects, is as yet but a small producer, owing to the lack of railways.

Bolivia.—The copper production of Bolivia for the year 1916 is estimated at 4000 metric tons, compared with 3000 tons in 1915. Almost all

[1] *Min. Mag.*

of this comes from the Corocoro district, now connected by railroad with La Paz and Arica.

The mines are owned by two companies, the Corocoro United Copper Mines, Ltd. and the Compania Corocoro de Bolivia. The latter company has four mines in operation producing between 200 and 300 tons of 4 to 6 per cent. ore daily. The United Co. operated three mills, using the same water successively and handling about 300 tons of 2½ to 3 per cent. ore daily. As is well known the output of the district is mainly native copper, the concentrate being known as "barilla." Since the completion of the railway line, the sulphide ore of the district is sacked and shipped to the sea coast at a cost of $5 per ton of freight.

The district was examined by engineers and geologists of the Anaconda Copper Co. in 1916, which held an option on one of the groups, but did not exercise it. The geology of the district is a matter of some controversy among geologists, but all are agreed that the copper occurs in pellets and grains of native metal in steeply tilted and well-mineralized beds of white sandstone, interbedded in a series of reddish shale and sandstone series of Tertiary age. There is also copper glance and domeykite in the *vetas*. The deepest workings at the Vyzcachani mine are 1250 ft. deep. The district has recently been described by Singewald and Miller.[1]

Canada.—Canadian copper mines produced a total of 119,770,814 lb., valued at $32,580,057, in 1916, compared with 100,785,150 lb., valued at $17,410,635 in 1915. This is an increase of 18.8 per cent. in quantity and of 87.1 per cent. in value. Of the total 1916 production, 27,007,166 lb. was contained in ores exported and 92,763,603 lb. in matte and bessemer copper; 5,551,166 lb. of copper, not included in above figures, was recovered by British Columbia smelters from imported ores.

Exports for 1916 were as follows:

	Pounds.
Fine copper, in matte, regulus and ore	124,942,400
Copper in pigs, bars, sheets, etc	2,430,400
Copper in scrap, etc	5,846,600

Imports in 1916 included 25,584,087 lb. copper in pigs, ingots and manufactures, valued at $7,565,377, besides the copper in brass, in copper sulphate and manufactured articles.

The most noteworthy development of the year was the opening up of two large copper deposits in the Flin-Flon Lake district, 650 miles northwest of Winnipeg and 90 miles northwest of Pas Manitoba. The Hammill, or Great Sulphide property in this district has 3,000,000 tons of $10 ore blocked out and the Mandy Mining Co. has 110,000 tons of ore running 22 to 28 per cent. copper, $3.60 gold and 9 to 16 oz. silver.[2]

[1] *Eng. Min. Jour.*, Jan. 27, 1917.
[2] J. W. Callinan, *Eng. Min. Jour.*, Feb. 17, 1917.

The finding of a great field of native copper ore in the far north, in the vicinity of Copper Mine River, on Prince Albert Island, promises to be an important discovery despite the extreme remoteness of the field, which is 1750 miles from Nome, or about 1800 miles from Newfoundland, via Baffin Bay.

In New Brunswick, the old copper mines near Dorchester, idle for 16 years, were re-opened.

Quebec.—The production of the province for 1916 was 5,707,200 lb., compared with 4,197,482 lb. in 1915. This comes from various mines in the eastern townships, which furnish pyritic ores valuable for their sulphur content as well as their copper. The ores go to the eastern United States and are smelted, or leached for copper after being burned in the acid plants.

Ontario.—The Ontario copper output for 1916 amounted to 44,997,035 lb., as compared with 39,361,464 in 1915, an increase of 12½ per cent. This is derived mainly from the nickel-copper ores of the Sudbury district and of the Alexo mine in Temiskaming, with a small amount shipped from six copper properties under development and a small recovery from the treatment of the silver ores of the Cobalt district. The Sudbury product is furnished by three operating companies, the Canadian Copper Co. (International Nickel Co.), Mond Nickel Co., and the British American Copper Co.

The ore is a basic segregation occurring in bays around the outcropping edges of a great mass of gabbro. The ore consists of pyrrhotite and chalcopyrite with admixed rock. It is roasted in open heaps and in part in mechanical furnaces to eliminate part of the sulphur and is then smelted to a low-grade nickel-copper matte in blast or in reverberatory furnaces. This matte is then blown in the basic-lined converters to form a blister metal carrying 77 to 82 per cent. of the combined metals. About 15 per cent. of the Ontario production is sent to Wales for treatment; the balance goes to the United States, a part of it going into consumption as Mond metal.

British Columbia.—This province produced 65,086,119 lb. in 1916, an increase of nearly 15 per cent. over the 1915 production of 56,692,988 lb. The greatest single producer of 1916 was the Granby Copper Co., whose product was 45,484,142 lb. Of the total copper output of the province, 17,181,837 lb. was contained in ores sent to the United States smelters and 47,904,282 in blister and matte.

There are three principal producing districts in British Columbia, viz., Kootenay, Boundary and Coast. The Kootenay region includes Rossland and the various mines of the Consolidated Mining & Smelting Co. of Canada, whose smelter is at Trail. Though the Rossland ores contain important gold values, they have but a small amount of copper. The 1916 production of the company was 4,446,080 lb. copper.[1]

Boundary District.—This district contains the mines near Phoenix, and Greenwood, owned by the Granby Consolidated Mining, Smelting & Power Co., and those of the Canadian Copper Corporation. The Phoenix mines yield direct smelting ores which are of contact metamorphic origin, occurring as flatly lenticular deposits replacing limestone in a breccia of igneous rock. The ore-bodies vary from small lenses, 50 ft. long and 5 ft. thick to the great deposits of the Knob Hill-Ironsides mine, which is 125 ft. thick, 900 ft. wide and 2500 ft. long.[2]

The mine output from 1910 to 1916 aggregated 5,853,164 tons averaging 1.1 per cent. copper. Reserves in 1916 were 3,610,000 tons carrying 1 per cent. copper and 75 cts. per ton in gold and silver. The cost of smelting and converting the ore for the year ended June 30, 1916, was $1.23 per ton and the slag carried 0.21 per cent. copper. Eighteen per cent. of the daily output of 3500 tons of ore comes from open-cut work using an electric shovel. The smelter at Grand Forks has eight blast furnaces and three converters in use.

Coast Districts.—The production of the British Columbia Coast districts in 1916 amounted to 43,048,065 lb. copper, as contrasted with 22,038,054 lb. from the mines of the interior districts. The Britannia, Anyox and Texada Island mines are the largest producers.

The Britannia mine, owned by the Howe Sound Copper Co., is said to be the biggest copper mine in the British Empire. It is credited with a positive reserve of 17,000,000 tons of 1.81 per cent. ore and a probable reserve of 30,000,000 tons. The ore carries chalcopyrite in chlorite schist; it is of medium hardness and breaks readily, loosening the chalcopyrite; it is of simple type, carrying twice as much iron pyrite as chalcopyrite, besides a little zinc blende and galena associated with quartz. A composite analysis of the mill feed in September, 1916, showed 2.74 per cent. copper, 7.95 iron, 1.5 zinc, 6 sulphur and 71.25 per cent. silica, with a trace of gold and 25 cts. silver a ton.

The 1915 production was 212,158 tons of ore milled and 30,123 tons shipped to smelter, containing 9,058,045 lb. copper, 50,306 oz. silver and 398 oz. gold. The ore picked from the sorting belt, amounting to 10 per cent. of the output, carries from 10 to 18 per cent. copper.

The ore occurs in 11 veins in a belt 800 ft. wide. These veins vary from 10 to 80 ft. wide showing an average stoping width of 30 ft. and are proven for 1000 ft. in length and a vertical height of 1600 ft. Development is by tunnels, the main haulage level at 2100 ft. above sea level

[1] Boston News Bureau.
[2] T. A. Rickard, *Min. Sci. Press*, Feb. 24, 1917.

being 4330 ft. long and 9 ft. by 13 ft. in section, the 1800-ft. level, 400 ft. higher and the 1600-ft. level, 600 ft. above the haulage tunnel. The mill has a capacity of 2800 tons daily. Costs aggregate 7.3 cts. per lb. of copper produced.

A reserve of 700,000 tons of broken ore carrying 2.74 per cent. copper is maintained in the shrinkage stopes; the total reserves are probably far greater than the 17,000,000 tons given in the company's report.

The Anyox, or Hidden Creek mine on Maple Bay, Observation Inlet, 600 miles north of Vancouver, is owned by the Granby Consolidated Mining, Smelting & Power Co. It has 18,000,000 tons of 1.45 per cent. copper ore assured. The smelter treats 3000 tons daily, converting part of the matte and sending the balance to the company's smelter at Grand Forks. The copper occurs in a heavy pyritic gangue, and averages 2.18 per cent. copper with 34 cts. in gold and silver. Costs in 1915 were $3.77 per ton or 10.09 cts. per lb. of copper produced.

In December, 1916, the Tyee copper smelter at Ladysmith, on Vancouver Island, was reported sold to American capitalists for $275,000. The purchasers include F. A. Sieberling, president of the Goodyear Tire & Rubber Co. Additions and alterations to the plant are being made under the direction of Mr. W. J. Watson with a view to increasing its capacity to 1000 tons of ore per day, as compared with the former capacity of only 600 tons daily. It is understood that a supply of copper ore is to be derived from the Mount Sicker mines in British Columbia and also from sundry Alaskan copper mines, as well as from customers elsewhere on the Coast.

The Marble Bay mines on Texada Island and the Rocher de Boule Copper Co.'s mine in the Skeena Country, were also important producers in 1916, the latter yielding between 2½ and 3 million pounds of copper.

Chile.—The copper exports of Chile for 1916 are officially stated at 71,430 metric tons, compared with 52,081 metric tons in 1915.

Chile has become the country of mammoth copper enterprises through the introduction of North American capital. Three large undertakings were in progress in 1916: Chile Exploration, Braden Copper and Andes Exploration.

The Chile Exploration at Chuquicamata, increased its production from 2 to 3 million pounds of copper monthly at the beginning of 1916, to over 4 million pounds monthly at the end of the year. Ore reserves are reported to have increased to 700,000,000 tons averaging 2 per cent. copper and the company claims an extraction of 80 and 90 per cent. at its plant. The copper properties of the Cia Minera de Calama were purchased by the Chile Exploration Co. in 1916. The company's engineers having solved all metallurgical problems, a larger plant will be erected and costs will be reduced as the tonnage treated is increased.

In April, 1913, the Chuquicamata deposit was estimated to contain 95,657,000 tons of 2.41 per cent. copper ore; latest estimate of ore reserves is 354,000,000 tons of proven ore, 346,000,000 tons of probable, or a total of 700,000,000 tons averaging 2.12 per cent.

If 27,000 tons are mined daily, it will take 34 years to exhaust the supply of oxidized ore alone, 239,000,000 tons. At the end of this period there would still remain 361,000,000 tons averaging 2.32 per cent. copper.

The company's plant began partial operation on May 18, 1915, and produced 10,944,824 lb. of refined copper at a profit of $30,468 in 1915. In 1916, the company produced 41,305,476 lb. and net profits were $4,102,202. Costs have been decreasing but are still high, due to the comparatively small production and to the increased cost of transportation and insurance, which is about 2 cts. per lb. above normal costs prior to the war.

The company's engineers estimate that upon completion of the plant, 27,000 tons of ore can be delivered to it daily; that the ore from the oxidized ore-body will average 1.91 per cent. copper and that an average extraction of 88 per cent. can be obtained; that 300,000,000 lb. of refined copper can be produced annually and delivered to Europe or the United States at an average cost of 6 cts. per lb. The extractable contents of the proven ore (354,700,000 tons) are calculated at 6,804,564 tons of metallic copper, which at the low profit of 6 cts. per lb. would yield gross profits of $816,547,680.

The present plant is producing over 6,000,000 lb. of refined copper monthly and this will be increased gradually until by the end of 1917, it should reach about 10,000,000 lb. per month.

Braden Copper Co. in the Province of O'Higgins continued to add to its ore reserve, and began important plant extensions with a view of treating 10,000 tons daily. At the end of 1916 it was treating about 4500 tons of ore per day, and in November produced 4,419,000 lb. of copper.

Mine development was pushed vigorously in the main Teniente ore-body, which in several places proved over 200 m. in width of good ore. It may be said of all these places that the foot wall was not found, for in none of them has the face of the workings been carried into rock below the commercially profitable limit of copper content.

During 1916 levels were opened and are in various degrees of development on A, B, C, D and E levels, which are lettered from Teniente No. 1 level upward. C level, 160 m. above No. 1, is driven out to the surface, where there is a town site, comprising staffhouse for foremen and shift bosses, with office, billiard and reading room attached; *cantinas* and *camarotes* for about 200 men; and *cuartel* for *carabineros*. This is the highest habitation of the mine, being about 9180 ft. above sea level. Development was carried on at a steadily increasing rate; the total advances for November, for instance, including the tunnel for the new electric railroad, were about 6000 ft.

The output at the end of the year was about 4500 dry tons per day, mostly from the Fortuna ore-body, which is of slightly lower grade than on the Teniente side; but the tonnage from the latter is gradually being increased as that part of the mine gets opened up, so that a gradual improvement in the grade milled is expected. The topmost levels in the Fortuna ore-body—that is, down to and including No. 2½—are now abandoned. Covering and drawing is proceeding rapidly above No. 3 level, together with some sublevel work.

At the mill at Sewell the capacity of the plant was gradually growing. Two Marcy mills were in regular operation, and a third is just awaiting the completion of its electrical equipment. The Hardinge mills on the two upper rows are all working with steel or iron balls, as are most of the third or lowest row. The reason for this change was to increase the output per grinding unit, though it does so at a slightly enhanced cost for balls over the old-time pebbles.

A new nodulizing kiln, 100 ft. long by 9 ft. diameter, was started in 1916, and another of the same size is being erected. In the power house regular air supply was provided both for the blast furnace and the converters by turbo-blowers, direct-driven by electric motors through flexible couplings. Both of these units gave entire satisfaction, and new ones were ordered of the same type for the extension of the plant.

Toward the end of 1916 a large part of the farm upon which the mine and reduction works are situated was purchased by the company to provide a site for a new smeltery lower down the river and to accommodate a new village and railroad tracks. The company also bought a tract of moorland, of about 10,000 acres, for the disposal of its tailings, as the government is not inclined to grant any further extension of the tailings-deposit system in the cañon of the Coya River.

In the matter of additional power, surveys were completed to utilize the water right granted by the government on the Pangal River, a tributary of the Cachapoal. Plans are now being made for the installation of three 5000-kw. units at this plant. Power will be transmitted from this generating station to connect to the one at Coya, whence it is transmitted to Sewell. Work was actively in progress, and the construction of a new power line from Coya to Sewell, via the new smeltery site at what is known as Caletones, was also under way. At the Coya power plant work was started on the foundations for a new 5000-kw. unit.

Land was purchased at Rancagua to provide additional yard space to facilitate the transfer from the broad-gage State railroad to the company's narrow-gage line. Some small improvements were made on the latter, but the greater part of the work to be done in this connection is still awaiting the report of the consulting railroad engineer who recently visited the property. New rolling stock was recently received in the shape of five Shay locomotives and two small switch engines, and 60 cars were being constructed at the plant.[1]

In 1916 actual work of development was begun on the Potrerillos property of the Andes Copper Mining Co., an Anaconda Copper Co. holding in Chile, about 62 miles in the interior of the Cordillera, from where the railway from Chanaral terminates, and in an absolutely sterile and deserted region.

When William Braden visited it in March, 1913, the place was virtually abandoned; the Potrerillos Mining Co., the former owner, had no capital and was in debt. Its mining property of low-grade ore was not profitable under the existing conditions of working and large sums of money were needed to construct roads, houses, etc., besides for solving the technical difficulties in treating the ore. Mr. Braden saw the possibility that a little exploration might reveal a large low-grade ore deposit and induced some of the men in the Anaconda Copper Mining Co. to take up this adventurous work. This work, which has already lasted 3 years, will be continued for some time longer; 3,500,000 pesos are said to have been spent in development work and the results have justified the expenditure, having revealed the existence of a great enough tonnage of 1½ to 2 per cent. copper ore to warrant the investing of a large capital for exploitation.

The Andes Exploration Co. was organized for the purpose of carrying on this work and actual development began in 1916. A railroad will be built between Pueblo Hundido and the ore deposit, about 62 miles, through the desert, and a hydro-electric plant will be erected for which it will be necessary to bring water from rivers in the interior by means of canals over 43 miles long. The company will begin work with a plant of 3000 tons daily capacity, increasing its capacity as the size of the ore deposit indicates. It will be necessary to construct port works in Chanaral.

The American Smelting and Refining Co., besides its Antofagasta activities, purchased the mines and smeltery at Caldera of the Chilean family of Edwards, and also acquired the Carrizal smeltery and associated properties.

The American Metal Co., of New York, had an engineer in the field

[1] R. S. Sorense, *Eng. Min. Jour.*, Jan. 6, 1917.

in 1916, but it was not learned whether any properties were definitely acquired.

All of the established smaller copper companies increased their outputs and made plant additions. Among these were: Société des Mines de Cuivre de Catémou, with an output of about 5000 tons of copper; Société des Mines de Cuivre de Naltagua, output about 4500 tons (both of these companies were installing coal-dust-fired reverberatories); Cia. de Minas de Cobre de Gatico, output 3600 to 3700 tons; Chili Central Copper Co., output 2600 to 2700 tons. The Lota, Guayacan and Incienso plants were also operated, as well as the Chañaral smeltery of the Société des Mines et Usines de Cuivre, which began basic converting. In the Collahuasi district in the north, the Poderosa Mining Co. shipped nearly 5000 tons of sorted ore carrying about 25 per cent. copper.

China (By T. T. Read).—There are a number of known copper deposits in China, but they are all worked by native methods and often under government control. The best-known mines are at Tungchuan and Huili in Yunnan and Ssu-Chuan; there are others in the other provinces. All that is definitely known regarding them has been given in the preceding volumes of MINERAL INDUSTRY, and no recent figures have been published, nor have any developments of importance occurred. The native output is insufficient to meet the domestic demand, and considerable amounts are, in normal years, imported from Japan. The government mints use some 12,000,000 to 15,000,000 lb. of copper per year in minting copper coins, and the native brass and bronze industry perhaps consumes an equal amount. The high price of copper since the war has led to the export of a good deal of old copper coin (cash) and brass to Japan for refining and resale.

Cuba.—The copper production of the Cuban Republic was 9311 tons in 1916 compared with 8836 tons in 1915. The latter amount was derived from 200,000 tons of ore mined in 1915, valued at $2,200,000, compared with 180,000 tons worth $2,000,000 in 1914. The following table shows the imports of Cuban copper ore into the United States from the Santiago district since 1909.

Years.	Copper Ore.	
	Tons.	Value.
1909	53,162	$586,890
1910	41,748	382,743
1911	66,323	490,007
1912	63,885	679,143
1913	22,614	570,369
1914	57,063	781,712
1915	28,488	1,004,344

The largest producer of the island is the Cuba Copper Co., operating the Cobre mine near Santiago. The 1120-ft., or deepest level of the mine, was fully unwatered in 1914 after being for a half century or more under water. Deep exploration has shown that the deposit is commercially mineralized to the lowest depths reached.

The company employs about 2000 men and treats 600 tons a day of 3 per cent. ore in a concentration mill using a Minerals Separation plant,[1] making a 16 per cent. concentrate that is shipped to the United States. The mine also yields high-grade ore shipped direct.

The discovery in 1915 of the Matahambre mine in Pinar del Rio, the west end of the island, and its successful development during 1916, into a very profitable shipping property, greatly stimulated prospecting in this end of the island and led to the opening of several rich copper deposits.

The most notable of these is the Candida mine, about 15 miles southwest of the Matahambre. The mine is owned jointly by ex-president Gen. Josè W. Gomez, B. Prida and Cardenas Cia. The property comprises 300 hectares in the foothills of the Organos range, the geographic backbone of the province. The ore-body is practically a prospect, for although it is proven for a width of 30 ft. by crosscuts from a 30-ft. winze and 8000 tons has been mined, the limits of the deposit are undetermined. One shipment of 7500 tons sent to New York in the summer of 1916 averaged 15½ per cent. copper, 6.25 oz. silver, 32 per cent. iron and 34 per cent. sulphur.[2]

The Soc. Minera Nieves is exploring a deposit near the Matahambre, and the Constancia mine near Vinales, formerly operated by the McLaughlins, until supposedly worked out, has opened up a new lens of high-grade ore.

Further exploration was in progress near Fomento, in Santa Clara, where the Cia Min. y de Fomento Watkins has opened a zinciferous copper deposit by an 800-ft. tunnel and a shaft.

Germany.—Although no official statistics of the copper production of Germany, for either 1915 or 1916 are available, the estimates given by the *Engineering and Mining Journal* are believed to be quite near the truth. This authority estimates an annual production of 35,000 metric tons for 1915 and the same amount in 1916. As the Mansfield mines produce in normal times 87 per cent. of the entire copper output of the German Empire and the *Electrotechnische Zeitung* gives the 1915 production of these mines at 20,176 metric tons, the total production of the empire for that year may be assumed to be 23,200 metric tons. On the other hand, there is not any doubt that the production of these mines will be crowded to the utmost degree possible and it may reach the 1911 record of 26,900 tons.

[1] Described in MINERAL INDUSTRY for 1915.
[2] *Eng. Min. Jour.*, Aug. 26, 1916.

Moreover, the Mitterberg copper mines which before the war yielded about 900 tons of copper annually, are owned by the Krupps and will lack neither capital nor labor in crowding production to meet the scarcity of copper brought about by munitions manufacturing.

It is evident that much of the copper used for shells is recovered and melted as otherwise even the enormous stock of copper acquired by Germany for the 3 years preceding the war, estimated at 2,000,000 metric tons, would be used up. The reported melting up of coins, statues, copper roofing sheets, hardly sustains the statement that the above amount is quite sufficient for 10 years' warfare—or that the supply of secondary copper is adequate for all needs. Statistics published by the Austrian Government[1] show that up to the end of August, 1916, 15,200 church clocks had been melted up, yielding over 16,470,000 lb. of copper.

Austria-Hungary, as well as Germany, secures some copper from the Balkans, including the Plakalnitz mine of Bulgaria and the Bor and Maidenpeek mines of Servia, the ores being smelted by the Upper Hungarian Mining & Furnace Co. at Susak. Copper ores are also smelted at Przibram in Bohemia and at Kärtner.

Great Britain.—The home production of copper by the British Isles is so small as to be almost negligible in the vast amount imported into the country. In 1915, the English mines produced 234 tons of copper from 822 tons of concentrates, compared with 341 tons from 2558 tons of concentrates in 1914. The imports from the United States alone jumped from 33,679,641 lb. in 1913 to 198,382,459 lb. in 1914 and to 201,182,665 lb. in 1915.

In 1916 the total imports of copper ore were 34,492 tons, as compared with 37,774 tons, but total imports of the metal including that in ores, regulus and precipitate, were much less than in 1915, the figures being 111,412 tons (249,562,880 lb.) in 1916 as compared with 180,386 tons in 1915. Despite the enormous purchases made in the United States and elsewhere, the imports from America were but 33,335 tons in 1916, as compared with 89,635 in 1915 and 96,991 in 1914. Imports for 1916 from Australia are reported[2] as 19,855 tons.

The British Government in December, 1915, forbade the purchase or sale, and all negotiations thereto, of any copper outside of the United Kingdom and directed reports to be made of all stocks of every kind. This was followed by a taking over of all copper in Great Britain. On March 1, 1916, the government issued a further order forbidding speculation in the metal, which was modified 2 days later to permit liquidation of all outstanding contracts for future deliveries, by May 31.

[1] *L'Echo des Mines et Met.*, Oct. 29, 1916, p. 216.
[2] Above figures from London *Min. Mag.*, Jan., 1917.

Governmental purchases of copper by Great Britain began March 29, 1916, with an order for 43,000 tons, followed April 7 by one for 40,000 tons and on April 10, by 50,000 tons. On Sept. 23, agents acting for the British and French Governments placed further orders for 200,000 long tons of copper or 448,000,000 lb., deliverable in 1917. This is the largest sale of copper ever made and is equivalent to one-seventh of the annual production of the entire world.

Japan.—The copper production of Japan for 1916 is estimated at 90,000 tons,[1] the country holding second place in the list of copper-producing nations, though its output is about one-tenth of that of the United States.

The 1916 production compares with 75,000 metric tons in 1915 and 69,816 in 1914. The industry has expanded under the influence of war prices and many new mines have been started, new smelteries erected and refineries enlarged. Only domestic ores are smelted, but heavy imports of Chinese coins, mainly brass cash, carrying 89 per cent. copper, have gone to the refineries, over 6000 tons a month being imported part

COPPER EXPORTS OF JAPAN.
(In long tons)

	Europe.	America.	China.	India.	Totals.
1906	23,997	3,628	5,757	82	33,464
1907	13,670	3,569	14,002	410	31,651
1908	25,000	5,515	2,220	2,766	35,501
1909	22,170	9,528	1,589	2,088	35,375
1910	21,116	8,846	957	4,218	35,137
1911	17,288	11,009	3,688	2,322	34,307
1912	23,351	6,917	7,317	805	38,390
1913	19,843	5,543	13,320	3,574	42,280
1914	19,642	5,207	13,577	3,274	41,700
1915	45,140	7,800	1,430	1,220	56,000
1916[2]	....	....	....	....	41,000

COPPER PRODUCTION OF PRINCIPAL JAPANESE MINES
(In metric tons)

	1912.	1913.	1914.	1915.	1916.[3]
Ashio	10,530	9,335	10,631	12,176	6,568
Kosaka	8,867	6,660	7,520	7,278	3,487
Hitachi	8,704	9,835	10,132	12,038	7,162
Beshi	8,537	7,523	7,446	7,500	4,593
Ozaruzawa	2,385	2,062	2,087	1,913	1,213
Ikuno	1,884	1,801	1,998	2,401	1,350
Furokura	1,719	....	....	....	....
Ogoya	1,540	1,441	1,482	1,658	1,039
Arukawa	1,413	1,056	919	805	790
Kamaishi	....	1,152	1,167	1,417	676
Ani	....	1,137	1,373	1,322	8,190
Other mines	23,299	9,749	10,691	36,500	....
Total	66,878	51,751	55,645	75,000	35,068

[1] *Eng. Min. Jour.*, Jan. 6, 1917.
[2] Nine months only.
[3] Seven months only. See *Eng. Min. Jour.*, Nov. 4, 1916.

of the time and one firm alone contracting for 200,000 tons. This has permitted greatly increased exports, half of which go to Russia, although not over 20,000 tons of new Japanese copper would be available. The Japanese exports for the past decade are shown in the following table, which conceals the fact that exports to Russia, amounting to but 5000 tons in 1914, had increased to 29,000 tons in 1915. Total exports for the first half of 1916 were 45,660 tons compared with 49,268 tons for the same period in 1915.

There are over 40 producing copper mines in Japan, 23 of which have an annual output of more than 1,500,000 lb., but the four largest mines, the Ashio, Hitachi, Kosaka and Beshi, produced 39,378 out of the total output of 75,000 tons in 1916, according to H. W. Paul.[1]

"The two largest mines and refineries are the Ashio copper mine and refinery of Furukawa & Co. and the Hitachi copper mine and refinery owned by Kuhara Mining Co., both situated north of Tokio and producing at present electrolytic copper at the rate of about 1100 tons a month. The output of these two mines during the first 9 months of 1916 was as follows: Ashio, January–September, 1916, 9972 metric tons (total 1915, 12,176 metric tons); Hitachi, January–September, 1916, 9965 metric tons (total 1915, 12,038 metric tons).

"The Ashio smeltery is working only upon ores from its own mine, smelting at present about 10,000 tons of ore per month, while Hitachi, having good transport facilities, produces about 30 per cent. of its copper out of ores from other mines. Both smelt their ores or concentrates in a semipyritic way down to a 40 per cent. copper matte, which is converted by the bessemer process into anode copper and electrolytically refined, a considerable amount of gold and silver being gained from the residues. The dust ore so far has been sintered by the Nakamura pot-roasting method, but recently more modern apparatus either has been installed already or is going to be installed for that purpose. In Ashio a 110-ft. reverberatory furnace is under construction for smelting the dust ore and six Wedge furnaces for drying the wet ore, and in Hitachi the Dwight-Lloyd sintering process has been installed. Only two other mines are producing over 3000 tons copper a year—the Beshi mine and refinery in Shikoku of the Sumitomo Co. and the Kosaka mine and refinery in northern Japan. Their production during the first 9 months of 1916 was: Beshi, January–September, 1916, 7039 metric tons (total 1915, 7886 metric tons); Kosaka, January–September, 1916, 5860 metric tons (total 1915, 7276 metric tons)."

Many difficulties are experienced by the Japanese copper refineries in the removal of poisonous dust and gases, large indemnities being an-

[1] *Eng. Min. Jour.*, Jan. 6, 1917.

nually paid for damages caused by smeltery fumes. The Hitachi smeltery erected an armored concrete smokestack 511 ft. high on a hill 1059 ft. above sea-level in order to cope with the smoke question, and another similar stack 567 ft. high is under construction at the new Saginesaki smeltery of the same company. Ashio, after its first installation to wash away the poisonous gases had failed, did not attempt to dilute the gases by means of a high stack, but erected several short and wide stacks and tried to dilute the gases by means of air fans after they had passed a dust chamber of an immense size; but neither did this very expensive installation come up to what was expected, the dust chamber catching only about 20 to 30 per cent. of the valuable dust. The Japanese government limits the SO_2 contents of smeltery gases to 0.35 per cent. during the months of April to September, while during the other months no restriction is made. Ashio is therefore forced to cut down the amount of ore smelted during the summer months, or at least it has to limit the sulphur contents of the ore smelted. These difficulties and the desire to take the best possible steps to cope with the ever-growing smoke nuisance induced a number of large mining companies in Japan to establish a research laboratory in order to investigate, on joint account, the dust nuisance, processes for the removal of poisonous gases and other matters of common interest. One of the first processes investigated by this research laboratory was the Cottrell electrical precipitation process, and after very successful trials were carried on at the Ashio smeltery, where the Cottrell apparatus collected 99 per cent. of the dust as compared with about 30 per cent. collected by a 600,000 yen chamber installation, the Cottrell patents for Japan were purchased by that concern.

Mexico.—The lack of law and order in Mexico and the continued robbing and murdering of American mining men, has crippled the copper smelting industry in all but the three districts of Nacozari, Cananea and Boleo; the first two, being close to the American border, continued operations intermittently. The copper production in 1916 was, however, very much larger than in 1915, amounting to 55,160 metric tons[1] compared with 30,969 tons in 1915, but falling more than 3000 tons below the record for 1913.

The paper money forced on the country by the various revolutionary parties depreciated so far that it was repudiated in many parts of the country, even by its sponsors. Railroad communication continued to be interrupted and supplies and labor scarce. Under these circumstances the output is most creditable and is largely due to the two large companies operating at Cananea and Nacozari, both in Sonora.

The Greene Cananea Co. continued operations at Cananea without

[1] *Eng. Min. Jour.*

serious interruption. The production for 1916 aggregated 62,250,067 lb. copper and 1,975,734 oz. silver, averaging over 5,000,000 lb. monthly, except in January. The cost is about 13 cts. per lb. including the Mexican taxes which are between 2½ and 3 cts. per lb.

The copper smelting plants of the American Smelting & Refining Co. remained idle.

Newfoundland.—Though rich in copper deposits, one of which has been worked by the Cape Copper Co. of England for a score of years, Newfoundland has no large mines in operation. The 1916 production is estimated at 1600 tons, compared with 1500 tons in 1915 and 2000 tons in 1914. Most of the copper ore produced in 1915, namely 12,150 tons valued at $151,372, went to the United States for treatment. The high cost of ocean freight offset the high price of the metal and the industry might have become completely moribund had not the Colonial government financed an electric copper smelting plant at St. Johns, erected in 1916, by Mr. Paul Simpson. This plant, which has an initial capacity of 125 tons per day, was operated throughout most of the year 1916, and has made practically all the copper used locally for cartridges and shells. The success of the smelter has not only made it possible to utilize the dumps at many of the old copper mines of the country, long closed down, but it has encouraged the owners of various small copper prospects to open up their properties with such success that two new smelters are already planned for Notre Dame Bay.

The Tilt Cove mine, which was worked throughout the year, after a practical shutdown of some 5 years, began shipments to New York in May. The property employed 150 to 200 men, both in mining and in sorting and shipping ore from the low-grade dumps.

Work was started at the Bobs Head property a few miles from Tilt Cove in 1909. Two exploratory shafts sunk in 1916 met with encouraging results.

Norway.—The Norwegian copper production comes mainly from the low-grade pyritic ores, a large part of the output being exported for acid making, especially to Sweden, which has been unable to secure Spanish pyrite since the outbreak of the war.

The production of metallic copper by local smelters amounted to 2860 tons in 1914, while that of 1915 was 2850 tons, or about 100 tons more than in 1913; of this amount 2545 tons was produced by three companies.

A brief review of the copper mining industry of the country, published by *L'Echo des Mines*, gives the following facts:[1]

[1] Quoted from *Eng. Min. Jour.*, Nov. 11, 1916. For an account of the smaller mines, see MINERAL INDUSTRY, 1915.

The Sulitjelma mine, in spite of many difficulties, produced a little more in 1914 than in 1913; the output being 125,600 metric tons of pyrites of export grade, 12,960 tons of smelting ore and 13,380 tons of Elmore flotation concentrates carrying 7.11 per cent. of copper; or a total production of 151,940 tons. There were smelted locally 27,075 tons of pyrites and concentrates, yielding 1475 tons of bessemer copper. New installations and improvements are completed; the mineralization in the mine is still good, and further increase of production is contemplated. The number of employees in 1914 was about 1667, of whom 632 worked underground. In 1915 the exploitation was about normal, with an output of 139,445 tons of export pyrites, 12,325 tons of smelting ore, and 14,719 tons of Elmore flotation concentrates carrying 7.43 per cent. copper; or a total output of about 166,489 tons. There were smelted 11,370 tons of pyrites and 13,611 tons of concentrates, which gave 1434 tons of bessemer copper. There were 1690 workmen employed in 1915, of whom 757 worked underground.

The Bossmo mines were shut down provisionally about the end of July, 1914, on account of the war; but re-opened on a small scale in November, 1914, with about 100 workers. There was a production of 15,000 tons in 1914 and 21,000 tons in 1915 of export pyrites, or nearly the normal output of 25,000 tons.

The Birtavarre mine, situated at Lyngen, began producing in 1910. It yielded about 450 tons of bessemer copper in 1914 and 486 tons in 1915.

The Lökken mines (Orkla Mine Co.) exported in 1914 about 69,370 tons of washed pyrites, 64,827 tons of pyritic lump ore and 5925 tons of copper ore; while in 1915 there were produced and exported 68,822 tons of washed pyrites and 108,611 tons of pyritic lump ore, or a total of 175,433 tons with 580 workers. Additions are being made to the plant, in order to increase production.

The Röros Kobberverk (organized in 1644 A.D.) increased its production from 493 tons of fine copper and 7700 tons of export pyrites in 1914, to 625 tons of copper and 8500 tons of pyrites in 1915.

The Röstvangen Gruber produced 18,025 tons of export-grade pyrites in 1914, of which 10,609 tons was exported. The average content was 2.75 per cent. copper and 43 per cent. sulphur. The concentrator having been completed, the production in 1915 was 8244 tons of lump pyrites, 5424 tons of washed pyrites and 620 tons of high-grade lump. From 500 to 550 men are employed.

The Foldal Copper & Sulphur Co., Ltd., produced 68,000 tons of pyrites in 1914 with 424 employees; and it is believed that the 1915 production was much larger. The Killingdal mine in Aalen (operated under lease by the Bede Metal & Chemical Co., Ltd.), produced about

17,568 tons of export pyrites in 1914 and presumably the same quantity, or slightly more, in 1915. The Kjöli mines, formerly worked by Belgian capital, suspended operations immediately after the outbreak of the European war; but will be taken over and operated by other interests. The Grong mines, operated by French capital, continued exploration and development work; but the transportation question has not yet been solved.

The Stordö mines produced in 1914 about 58,255 tons of crude pyrites yielding, after concentration, 26,400 tons of export grade, nearly half of which was exported. In 1915 the yield was 36,281 tons of export pyrites, with a force of 170 employees. The Svano mines produced about 8000 tons of pyrites annually in 1914 and 1915, with 70 men; and at the Karmo, Rödfjeld, Fosdalen, Undal and Meraker mines there was a slight production during 1915. At the Björkaasen mines some tonnage of pyrites has been blocked out and work has been conducted on a small scale, but on account of the war the projected plant was not constructed.

The 1914 pyrites production was about 420,000 tons, of which 360,000 tons was exported and the remainder consumed in Norway. In 1915 the pyrites production amounted to 525,000 tons, of which 460,000 tons was exported. Since the beginning of the European war nearly half of the Norwegian pyrites production has been exported to Sweden—probably 200,000 tons annually—chiefly because of the difficulty of moving the usual supply of Spanish pyrites to Sweden.

The total value of copper and pyrites production, at Norwegian ports, amounted to about $4,000,000 in 1914 and about $7,000,000 in 1915, the selling price being higher during the latter year.

Peru.—The copper production of Peru far exceeds in value that of all other metals, though the country was the treasure house of the Incas and the main source of gold and silver shipped to Spain by the Conquistadores.

The copper produced in 1916 amounted to 41,625 metric tons, as compared with 31,890 tons in 1915 and 25,070 tons in 1914. The Cerro de Pasco district is by far the largest producer, 75 per cent. of the output for the years 1901 to 1915 inclusive being 340,000,000 lb. of copper valued at $50,000,000, recovered from 2,358,000 tons of ore that averaged 7.2 per cent. copper, 8.4 oz. silver and about 0.1 oz. per ton gold. The highest monthly output, in July, 1916, was 3,250,000 lb., or at the rate of 55,000,000 lb. copper yearly. The Backus & Johnston Co. operating at Casapalca produced 8638 tons of copper in 1916.

The Cerro de Pasco Mining Co. owns 5900 acres of mineral land in the district of this name 210 miles by rail from Lima and at an altitude of 14,000 ft. The mines, worked for silver ores for centuries, consisted of hundreds of pits and holes with great caved-in areas. This entire tract has been systematically opened up by over 20 miles of underground workings and drained by the Rumilliana tunnel, about 450 ft. below the old surface. There are five main shafts, the Esperanza, whose workings are 700 ft. deep, being the main ore-hoisting shaft.

Ore reserves in 1916 aggregated 3,000,000 tons including both first- and second-grade ores. The ores consist of semicrystalline sulpharsenates—enargite, fomatinite, luzonite and some tetrahedrite in a gangue of silica, pyrite, barite, sphalerite and galena, also varied oxidation products. These ores occur in veins and fractures in limestone, but an extensive mass of quartz porphyry with a capping of fragmental material, forms the west wall of the great fracture zone and limestone the east wall.

The smelter, 9 miles from the mines, handles ores from Morococha and other points, only 60 per cent. of its product coming from the Cerro de Pasco.

The Morococha Mining Co. is a subsidiary of the Cerro de Pasco Co. and owns the principal mines of the district of this name, second only to Cerro as the most active and important copper-silver producing district in Peru. The copper occurs in primary enargite, tetrahedrite, bornite and chalcopyrite, as shoots and veins in igneous rocks and limestone, and in contact-metamorphosed limestone.

The veins are opened by long tunnels and are estimated to have reserves for 10 years to come if production is maintained at the present figure of 115,000 tons a year. About 750 men are employed at this camp and 1200 at Cerro. The Peruvian export tax, paid by the Cerro de Pasco Co. in 1916, amounted to £192,525. The Backus & Johnston Co., the next largest producer, paid £39,969.

The Casapalca district is also a producer of copper as a by-product of the silver production; the product is handled by the Backus & Johnston Co.

The Cie. des Mines de Huaron continued the development of its copper mines, about 35 miles from Cerro de Pasco, and was to erect two 150-ton furnaces shipped from the States. A. J. Bennett and associates optioned the Sayapullo copper-silver mines, "inside" from Trujillo, about 80 miles beyond railhead of the Salaverry-Ascope line; development in 1916 was extremely gratifying and the 3-year option will probably be exercised. Quiruvilca district produced about 3000 tons of hand-sorted copper ore, taken out on pack animals for 100 km. to the railroad terminal, 60 km. from the port of Salaverry.

In the district of Hualgayoc, exploration of the copper-silver mines was continued by the Cia. Socavón Purgatorio and the Soc. Minera Italia de Hualgayoc; silver recovered by lixiviation was shipped from this district via Chilete to the port of Pacasmayo. Agustin Arias, of Cerro de Pasco, continued the development of his Magistral copper properties, and in a small furnace smelted 7 to 12 per cent. ores to a 50 per cent. matte, exported from Chimbote; the Magistral district is 154 km. from Chuquccara, the terminal of the railroad from Chimbote.

One of the important events of 1916 in southern Peru was the optioning of Cerro Verde by the Andes Exploration Co. This large low-grade deposit, formerly controlled by Carlos Lohmann, is only 12 km. from Tiabaya, a station on the Ferrocarril del Sur 171 km. from the port of Mollendo.

Russia.—The production of refined copper in Russia for years past is as follows, in metric tons.

	1913.	1914.	1915.
Urals	17,283	16,760	19,924
Caucasus	10,003	7,123	} 9,540
Siberia	5,656	5,616	
Chemical and refining works	1,380	1,560	966
Total	34,322	36,430	29,800

Though the production of copper increased steadily prior to the war, it has decreased since 1914, the production for 1915 being but 29,800 tons, as compared with 36,430 tons in 1914 and 34,300 tons in 1913. The suspension of work by the Caucasus Copper Co., owing to the occupation of the mines by the Turks and to labor troubles, caused the decline.

Before the war began, Russia produced but 75 per cent. of the copper consumed in the country, despite a high protective duty which at normal exchange amounts to about £34 per ton. About 50 per cent. of the output is produced by Anglo-Russian companies.

The Kyshtim mining works is the largest producer, yielding nearly 8000 tons of copper per year; this company owns great estates in the Ural mountains, containing copper and iron mines and smelting plants. The company's report for 1915 shows that 7642 tons of copper was produced from 361,750 tons of ore mined that averaged 3.05 per cent. copper, $1.80 gold and 1.1 oz. per ton silver. Production in 1916 amounted to 6566 tons. Four mines were operated, the Smirnoff yielding 145,105 tons, Konnikhoff 110,920 tons, Amerikansky 31,026, Tissoff 73,454 tons and Ivan 1245 tons. The coarse smelting ore is treated in blast furnaces at Karabash, the fines in reverberatory furnaces at Kyshtim, the matte going to the Karabashi smelter for bessemerizing.

Reserves, based on development and drilling, aggregate 2,535,000 tons, an increase of 845,000 tons, during 1915. The ore ready for stoping

May, 1915, was 353,000 tons carrying 2.9 per cent. copper. The 1916 production was 6600 tons.

The Tanalyk Corporation, owning all the shares of the South Urals Mining & Smelting Co., a Russian corporation, is under the same control as the Kyshtim. The chief copper mines are the Tanalyk, Mambet and Ulali, with two gold properties. A reverberatory smelting plant was erected in 1914 and a blast furnace added in 1915. During the year 1915, the smelting plant treated 33,445 tons of ore yielding 605 tons of blister copper averaging 98.14 per cent. copper, 19.38 oz. gold and 170 oz. silver per ton. During the first 8 months of 1916, the production was 420 tons of blister copper averaging 98.39 per cent. copper, 28.89 oz. gold and 204.8 oz. silver. For the entire year the output was about 616 tons. The cyanide plant produced 1906 oz. gold and 752 oz. silver, from August to the end of December, 1915.

The 1916 production is about 26,000 oz. gold and 135,000 oz. silver. The plant is being altered in order to improve extraction without interfering with its operation.

The reserves of definite sulphide ore are as follows: Mambet 55,000 tons averaging 2.35 per cent. copper, 6.57 dwt. gold, and 6.7 oz. silver; Ulali 28,300 tons averaging 2.3 per cent. copper, 6.5 dwt. gold, and 6.6 silver; Tanalyk 7500 tons averaging 3.54 per cent. copper, 3.44 dwt. gold, and 2 oz. silver; and 5400 tons at the Troitzk and Yapaensky. The total reserves, June, 1916, are reported at 290,000 tons. Of oxidized ore reserves there are 82,000 tons at Semeonovsky, averaging 12.2 dwt. gold and at Tuba 48,000 tons averaging 1 per cent. copper, 68 dwt. gold and 20 oz. silver. The 10,000 tons of sulphide ore in reserve at Tuba are estimated to average 13 per cent. copper and 1.4 dwt. gold.

Other Russian producers are the Bogoslov, which before the war produced 4000 tons of copper annually, the Spassky and the Sissert, in all of which English capital is invested. The purely Russian companies include the Demidor at Nijni Tagilsk, the Verch, Issetsk, in the Ural and the Alla Verde and Siemens companies in the Caucasus.

Servia.—The copper production in Servia passed under the control of the Austrians in 1916, as a result of the war and the two largest mines, those of Bor and of Majdenspek, are again being worked, yielding "3 carloads" of blister copper per day, besides pyrite for sulphuric acid production. The Bor mine yields 69 per cent. ore which is smelted to 90.6 per cent. copper. The production in 1912–13 was 7600 tons.

Spain.—The copper production of Spain has undoubtedly greatly increased under the spur of the English demand, but the figures are guarded as a war secret and can only be estimated. The following table gives the known production up to 1915.

COPPER OUTPUT OF SPAIN AND PORTUGAL

(Long tons)

	(a) 1911.	(a) 1912.	(a) 1913.	(b) 1914.
Rio Tinto	33,385	39,925	36,320	21,515
Tharsis	3,395	3,375	3,220	3,605
Mason & Barry	2,920	3,540	3,135	2,265
Sevilla	1,530	1,390	1,510	1,435
Other mines	9,700	10,700	9,650	7,695
Total	50,930	58,930	53,835	36,515

(a) Henry R. Merton & Co.
(b) *Comm. Rept.*, Sept. 2, 1915.

The copper district of the Spanish peninsula extends across the border of Spain into Portugal, but the Huelva district contains most of the big producers, including the Rio Tinto, so often quoted as the oldest productive copper mine of the world. Practically all the ores of the Spanish deposits are pyritic and of such physical nature that they are in great demand for sulphuric acid manufacture. This fact has greatly influenced the methods of ore treatment, much of the ore being "washed," that is, leached of its copper content and then shipped as sulphur ore with but low residual copper content. The copper obtained by leaching the ore is in part exported as precipitate, though most of it is smelted.

The following table gives the exports from Spain up to the latest available date (figures are given in metric tons[1]).

	January–December.		
	1914.	1915.	1916.
Copper, precipitate	10,056	10,443	11,432
Copper, black and old copp r, bronze and brass	230	254	1,736
Copper ingots	14,828	15,685	12,634
Copper bars	103	372	261
Copper sheets and nails	....	....	21
Brass sheets	....	....	242
Rolled copper, brass and bronze	78	267	1,196
Copper ore over 2½ per cent. Cu	52,378	16,340	21,239
Copper ore under 2½ per cent. Cu	29,921	13,179	24,386

It will be noted that the amount of old copper sent out of the country and of brass sheets, etc., though greatly increased in 1916, did not offset the decrease in ingot bars, while the exports of ore, though larger than in 1915, were very much less than in 1914.

Dividends of 95s. per share were paid in 1916, contrasted with 55s. in 1915, 35 in 1914 and 75 in 1913. The highest previous dividend was 90s. in 1912.

Rio Tinto.—The output of this company in recent years is summarized in the following table:

[1] *Metal Bull.*, Mar. 6, 1917.

OUTPUT OF RIO TINTO MINES
(In long tons)

Year.	Pyrite for Shipment.	Ores for Local Treatment.	Total Mined.	Average Copper Contents, Per Cent.	Copper Produced at Mines.	Pyrite Sold.	Washed and Other Sulphur Ores Sold.
1903	688,919	1,229,619	1,918,538	2.390	21,565	667,748	118,174
1904	672,344	1,276,475	1,948,819	2.340	21,218	663,744	157,810
1905	627,336	1,202,768	1,830,104	2.363	19,530	660,724	308,184
1906	655,328	1,268,388	1,923,716	2.411	21,287	632,307	477,843
1907	641,858	1,265,090	1,906,948	2.417	21,251	607,944	619,814
1908	604,275	1,115,610	1,719,885	2.265	24,256	589,815	668,477
1909	604,799	1,184,188	1,788,987	2.349	24,364	600,946	569,604
1910	637,020	1,509,945	2,146,965	2.097	22,790	578,443	683,605
1911	649,215	1,536,390	2,185,605	2.144	21,880	662,259	841,964
1912	698,399	1,708,573	2,406,972	2.180	25,623	668,861	977,812
1913	652,168	1,207,403	1,859,571	2.190	21,062	635,900	825,408

The Huelva Copper & Sulphur Co., one of the few copper companies working in southern Spain that publish details of their operations, has, under the management of H. F. Collins, retrieved the ill luck of former years and has applied the profits of the last 2 years to writing off depreciation of their plant. Mr. Collins introduced smelting for the greater part of the ores, instead of selling them for copper and sulphur content. During the year ended June 30, 1915, 71,071 tons of ore was mined, of which 57,446 tons was smelted, the rest going to the leaching floors. The production of copper for the year 1915 was 1707 tons, compared with 1222 tons in 1914. The increased price received for the metal was offset by the 50 to 100 per cent. increase in coal and coke supplies. Further exploration of the property has been ordered as the ore reserves are not sufficiently far ahead of smelter requirements. In order that more of the low-grade ore shall be handled, the leaching floors will be greatly enlarged. An electrolytic refinery is planned for the ensuing year.

Esperanza Sulphur & Copper.—The company was formed in 1906 to acquire the Esperanza, Forzosa, and Angostura pyrite mines, in Huelva Province, southern Spain. T. D. Lawther is managing director. Small dividends were paid for the years 1908 to 1912, on the capital £350,000. At the time of the formation of the company, £100,000 debentures were issued to the vendors, and up to the end of 1915, £56,990 had been redeemed. In May, 1916, it was decided to redeem the balance of the debentures, £43,010. The report for the year 1915 shows that a smaller amount of ore was mined owing to the decrease in demand caused by the war, but the actual amount of ore shipped from Huelva was not much less than during 1914. At the Angostura mine, 41,774 tons was mined, as compared with 47,426 tons in 1914, and at the Esperanza and Forzosa 44,514 tons was mined, as compared with 63,497 tons. The reserves are estimated at 307,000 tons at the Angostura, and 431,000 tons at the Esperanza-Forzosa, falls of 33,000 tons and 52,000 tons respectively as compared with the figures a year ago. The copper precipitate produced during the year was 135 tons. The shipments of ore from the port of Huelva were 89,224 tons, 9527 tons less than during the previous year. The trading profit for the year was £25,680, out of which £2183 was paid as debenture interest. The remainder, with the balance from the previous year, was devoted to the redemption of the outstanding debentures, as already mentioned.[1]

Venezuela.—In Venezuela the South American Copper Syndicate shipped over 5000 tons of crude ore besides matte, and returns for its fiscal year are reported as $450,000, or more than double the 1915 returns.

The Cumaragua Co. continued development in the Aroa district. The newly formed Sindicato Aleman, Minas de Cobre de Santa Isabel, continued development work throughout 1916 on the Santa Isabel copper mine, south of Villa de Cura.

Metallurgy of Copper in 1916

By L. S. Austin

Summary of Progress in 1916.—The year 1915, especially the latter half, was a period of great activity in increasing equipment in established works—a time of free expenditure of capital. In 1916 the new equipment was brought into operation, and the output of copper was largely increased.

Copper in 1916 advanced in price from 22 to 33 cts. per lb. by the close of the year, while production for the first half of 1917 has been sold at a price around 30 cts. and, for the duration of the war, this seems destined to continue. Stimulated by high prices, the copper companies have succeeded in increasing their production by 30 to 50 per cent.

The remodelling at Anaconda and Great Falls was completed and brought under operation during the year, and both the reduction works are operating on the new basis. The normal monthly output at the Washoe works is 25 to 26 million lb. of copper monthly. The coal-fired reverberatories and the 20-ft. Great-Falls-type converters have given entire satisfaction, though at El Paso the new Pierce-Smith type, 13 ft. in diam., seems to be a competitor. At the Washoe plant the 28 Anaconda-Wedge furnaces are roasting with success flotation concentrates containing 3 per cent. sulphur at the rate of 150 tons per furnace daily. This has proved profitable, due to the fact that a Cottrell apparatus effectively saved the flue-dust.

Cottrell treaters are used at both the drier and converter plants of the International Smelting Co., Miami, Ariz.

[1] *Min. Mag.*, June, 1916.

At the Ajo works of the New Cornelia Copper Co., the construction of a large leaching plant is under way.

The feeding device upon the new or No. 4 furnace at Anyox seems to be an advance on others in that the charge can be distributed according to the rate that the plunger is advanced. It is the same idea as that at Mt. Lyell, except in the latter case the pushing of the ore into the furnace is done by hand.

Anaconda produced 336,900,000 lb. of copper in 1916, all but 24,-000,000 lb. having come from the company's mine. The Chile Copper Co. yielded 6,118,000 lb. in December, 1916; it is expected this will be increased to 10,000,000 lb. monthly in 1917.

Besides the recovery of copper mineral by flotation, sulphuric acid manufacture, copper leaching, and leaching of copper ores have come to the fore. Indeed flotation and leaching as rival processes bid fair eventually to supplement one another.

The Arizona copper companies, which produce oxidized concentrates, are experimenting on methods of leaching them. One scheme is to dissolve the contained copper by means of dilute sulphuric acid and precipitate upon iron, wasting the resultant barren solution. This avoids the difficulty of trying to save the solution from a more or less colloidal slime. Due to the fact that the roasting furnace is now called upon to treat a flotation product so fine that flue dust is inevitably made, there comes the question whether such fine material, running largely from 100- to 500-mesh, should not be leached.

At Chuquicamata it has not been possible to obtain magnetite anodes made in Germany, so anodes of duriron have been used, and recently ferro-alloys have been tried. Of course, when these become partly corroded, a magnetite anode results. At this plant the nitrates by attacking the cathodes, at present cut down electrolytic efficiency; and the chlorides must be neutralized by means of shot-copper, the copper being recovered from the solution later. Fortunately, the sulphates are abundant in the ore, so that there is no fear of acid shortage.

At Ajo, at the new 5000-ton plant, construction of 11 lead-lined tanks 88 by 88 by 15 ft. deep is completed; also two 7500-kw. turbines have been installed for power purposes.

Reverberatory furnacing is taking the leading place over its older rival, the blast furnace. This is due to the large amount of fine material which has to be smelted. Briquetting such fine products is but a palliation.

It will be seen that the Cottrell apparatus is increasingly in use in the recovery of flue dust, due to the fact that it is not corroded or destroyed by the sulphur gases present in roaster or converter and valuable by-products are obtained. Incidentally, the visible fumes removed by it aid in dispelling the objections of the smoke farmers.

The total supply of copper available from American copper refineries in 1916 was 2,400,000,000 lb. of which 2,173,000,000 was from domestic sources.

Ore Handling

Industrial Locomotives.[1]—W. C. Capron and C. R. Kuzell[1] of the Washoe Reduction Works discuss departmental haulage in smelting plants. Safety, utility and other causes permitting, the cheapest motive power is used. Thus one locality may have cheap coal, another hydro-electric power, a third cheap gasoline and oil.

Steam locomotives can go wherever a track is laid. Electric locomotives have a trolley wire, but by using crab and reel attachments, can utilize tracks that lack power supply; a storage-battery locomotive can, however, go anywhere. Compressed-air locomotives are well adapted to locomotive service, but have an efficiency of but 18 per cent. Gasoline locomotives have a low first cost, but are not well adapted to intermittent service, due to low power efficiency. All these locomotives have short wheel bases to permit them to traverse sharp curves and crooked tracks.

While the internal-combustion engine appeals to one for its high fuel efficiency, in active practice, with numerous starts and stops, it is necessary to run the motor while idle during stops, thereby wasting fuel; moreover, the starting effort is low as compared with a steam or compressed-air locomotive.

At three western copper smelteries the comparative cost data of the respective steam, electric and compressed-air systems are as follows: For steam, using 17-ton locomotives costing $4000 and handling 150-ton loads, the cost per engine-day of engine upkeep was $6.84, for coal $0.80. The total cost per ton was $0.0551 and per ton-mile $0.086. At the electrical installation there were motors of 13 to 26 tons, the small ones costing $3500, the large $8000. The train loads were 75 tons of 20 cars. The cost per engine-day for engine upkeep was $9.86 and for electricity $4.52. The total tramming cost per ton was $0.0526 and per ton-mile $0.0926. Finally, where there were compressed-air locomotives of 15 to 22 tons, hauling loads averaging 90 tons, and costing $4500 each for the small size, $6000 for the large, the cost for engine upkeep was $3.60 and the power cost $14.25 per engine-day. The cost per ton for hauling was $0.064 and per ton-mile $0.1194.

Tram Cars, Matte and Slag Cars.[2]—Cars intended for the transfer of materials at smelting works are of steel, and commonly of the bottom-

[1] *Eng. Min. Jour.*, **102,** 613.
[2] *Eng. Min. Jour.*, **102,** 617.

discharge or of the rolling side-discharge U-type, the discharge gates made as large as possible.

At Anaconda the blast-furnace charging car has a rectangular body with side doors; by tipping this body, using a compressed-air cylinder, the charge slides into the furnace. The car, empty, weighs 5100 lb. and will hold 60 cu. ft. (say 3 tons). These cars have mostly a 4-ft. to 4.5-ft. wheel base.

The U-type side-discharge car has no gates and may be dumped to either side. The car is well adapted for handling refuse to the dumps or granular material to storage piles. Such a car, of 100 cu. ft. or 5 tons capacity, will weigh 3800 lb. This type may be used for wet concentrates.

Drop-bottom cars can handle run-of-mine coal; where lumps, such as furnace accretions, are loaded the discharge gates must be large. Some such cars have large hinged bottom gates wound up by means of chains, or in discharging, pried up with a bar and held there by a catch. For wet concentrates a large car of 13 tons capacity is in use, having two discharge gates for complete emptying. It weighs 6700 lb. Fine dry material, such as calcine or flue dust, needs a car having at least a partly enclosed top. Just enough top opening is left so that the car can be readily spotted under the loading chute. A recent well-constructed calcine car of 15 tons capacity is equipped with air brakes and has light pneumatic discharge gates. Flotation concentrate is a difficult material to handle. It may have a temperature of 500° C., flows like water, and will find its way through the finest holes, so that by ordinary handling dense clouds of choking fumes and dust are liberated, causing discomfort to the men and dust loss. To eliminate partly such loss in loading the receiving openings are made no larger than to take the stream from the calcine-hopper spout. For emptying the car a new type of discharge gate has been devised. By a vertically movable collar this is telescopically connected to the receiving hopper over the furnace.

Frederick Laist describes[1] the method arranged for unloading the fine flotation concentrate at a reverberatory furnace. The charge hoppers, one at each side, are 60 ft. long. These are equipped with unloading tunnels, just large enough in cross-section plus a 6-in. clearance to admit the train of calcine cars. In this tunnel is a fan-draft drawing away the dust-laden air created when the cars are discharged. The workmen in consequence do not breathe the dust. The dust thus removed can be settled and recovered, but thus far it has not paid to do this. We also call attention to the concentrate and calcine cars at Miami, pp. 241, 242.

Molten matte is received into clay-lined 12-ton ladles. Otherwise a

[1] *Eng. Min. Jour.*, **102**, 627.

heavy cast-iron or cast-steel ladle may be used, but the metal must be protected from the washing effect of the incoming stream of molten matte.

To handle slag, a car carrying a 30-ton ladle is preferred. This ladle is of 300 cu. ft. capacity, and is dumped by means of compressed air, the whole contents being instantly thrown over the dump, skull and all.

Coal-pulverizing Plant.[1]—C. R. Kuzell gives a flow sheet and illustrated description of the 1000-ton (daily) plant at Anaconda, Mont.

Run-of-mine coal, coming in railroad bottom-discharge coal cars, is discharged into an 80-ton feed-bin. From this it is drawn in regulated quantity to 30- by 30-in. Jeffrey single-roll crackers where it is coarse-crushed, then raised and distributed to a 1000-ton crushed-coal storage bin. Coal from these crackers may indeed be sent directly into the pulverizing plant, the over-supply only being sent to storage. By belt conveyor, coal from storage is drawn upon conveying belts and by chain elevator to chutes feeding the three Ruggles-Coles dryers.

The discharge from the dryers can now be readily crushed to pea size by rolls. This fine product is transferred by screw conveyors and chain elevators to the 80-ton bins in the pulverizing plant in another building. Here it is pulverized by 10 Raymond five-roller mills, the dust withdrawn from the mills by exhausters to Cyclone dust-collectors. The product, now sufficiently fine, is taken by screw conveyors to the 50-ton coal-dust feed-bins of the respective furnaces, of which there are nine. We may note that the coarse coal is transferred by belt conveyors until it has been dried and crushed, while the screw conveyor is found to be quite satisfactory for the dry, fine, light final product.

Pulverized coal for satisfactory service should be dried to less than 2.5 to 3 per cent. moisture, and should be so fine that 95 per cent. is finer than 100-mesh size and 80 per cent. finer than 200-mesh. The coal should be so dry that it will not pack or ball up when being fed to the furnace, and yet enough moisture should remain that there shall be but little risk of catching fire or of explosion. The loss of heat due to the presence of 1 per cent. moisture, for example, is negligible, being no more than 0.1 per cent. of the total evolved in burning.

Roasting and Smelting Practice

Blast-furnace versus Reverberatory Smelting.[2]—For the treatment of gold-copper ore at the Mt. Morgan Gold Mining Co., Australia, but a slight difference was shown for either kind of treatment, the blast-furnace method being favored.

It will be seen that the costs either by the blast furnace or by the re-

[1] Paper at 2nd Pan-American Sci. Cong.; *Eng. Min. Jour.*, **101,** 302; *Min. Sci. Press*, **112,** 202.
[2] *Eng. Min. Jour.*, **102,** 608.

verberatory figure out nearly the same at this particular locality. To summarize:

The blast furnace has the advantage that higher-grade ore, known to exist in the mine, can be more profitably treated, that variations in the ore can be quickly met; that the present plant, being a blast-furnace one, can be quickly changed and added to, and that the process is well known and tried. The drawbacks are that much concentrates and flue dust must be sintered, that perhaps in 8 years the smelting ore will be exhausted and that the price of coke may seriously increase.

The reverberatory has the advantage that there would be a saving in capital invested (?), that concentrates and fine ore are advantageously treated, that the water-supply is sufficient, and that neither siliceous nor iron fluxes would be needed. The disadvantages would be lack of experience of trained men, large losses in roasting flotation-concentrates, and that coal would have to be imported.

Smelting Finely-divided Ores.—M. W. Krejci and C. R. Kuzell have patented a process for smelting finely-divided ores, such as flotation-concentrates, by blowing into a smelting cylinder or into a reverberatory furnace a mixture of the ore with powdered coal, using a regulated supply of air. The process is arranged to take either oxidized or sulphide ores. In either case the proportions of air, fuel and ore are so regulated as to give the desired product, whether blister copper, as in the case of oxidized ores, or matte of suitable grade from sulphide ores. The ore particles are raised to the fusion point, and falling to the bath of the furnace, receive their additions of sulphides and fluxes to make a suitable slag and matte. The object sought is to envelop such particles with a gaseous film, thereby ensuring the almost instantaneous smelting of the ore and in an economical manner.

Smelter Practice at Anaconda.[2]—In 24 of the 28 Wedge-Anaconda type 25-ft. furnaces at the No. 2 roaster plant there is put through daily 1700 tons of flotation-concentrates with which is mixed 500 tons of ordinary concentrates from the bins and 200 tons of fine lime-rock, being 100 tons of charge per furnace. To lessen flue-dust loss from such fine material the furnaces are run with a minimum of draft, an ample dust-chamber has been provided, and also a Cottrell treater capable of handling 400,000 cu. ft. of hot gas per minute. Corrugated sheets set at 12-in. intervals fill the interior of the treating chamber. Chains hung midway between the plates form the positive electrodes. This is called the "box type" of treater in contradistinction to the "pipe type"

[1] U. S. Patent 1,180,621; 1,164,653; *Eng. Min. Jour.*, **101**, 479; *Met. Chem. Eng.*, **14**, 397; *Min. Eng. World*, **44**, 789.
[2] *Eng. Min. Jour.*, **102**, 635.

elsewhere used. The roaster shaft runs on a step which has replaced the roller bearing at first used, and which gave trouble.

Owing to the abnormal demand for copper the blast furnaces are in full operation. This is, however, temporary, and eventually but one furnace will be used in order to smelt exceptionally high-grade ore, matte, slag cleanings and barrings from the roasting furnaces.

No. 9 reverberatory furnace at the converter plant is not in operation, since the blast furnaces can use all the converter slag. When they are shut down it is intended to operate this reverberatory on a siliceous charge high in sulphur, so as to provide silica enough to produce a slag of 37 per cent. and a rather low-grade matte, which can be poured back in the converters. The continuously flowing slag is to be granulated.

Blast-furnace and reverberatory slag at the plant has always been granulated and sluiced away. Due to the height of about 85 ft. above the flat below, there has been an extensive dumping ground. This area has finally been so filled that a new system has had to be used. A small pond or sump is maintained at the end of each discharge launder, and from the sump the granulated slag is removed as it accumulates by the grab-bucket of a large electrically operated locomotive-crane, which loads into a train of six 30-ton cars. Dumping is so managed as to form a saucer-shaped dump, rising with a grade of about 2 per cent. from the sumps. In this way dump storage has been increased to take care of the slag for the next 30 years.

Smelting Results at Greenwood, B. C.[1]—One furnace is running on a more refractory charge than formerly, so that the tonnage is reduced, being 775 tons daily, The coke used is 14.44 per cent. of the charge; it contains 22 per cent. of ash. To treat the tonnage an average of 49.2 men were employed at an average wage of $3.48 per day. The principal item of the charge is Mother Lode ore, containing SiO_2, 28.5 per cent.; Fe, 21.2; CaO, 17.7; S, 3.15 and Cu, 0.8746 per cent.; also Au, 0.037 and Ag, 0.21 oz. per ton. The ore is accordingly self-fluxing, and yields its own matte, so that, in spite of its low grade, it can still be smelted with profit. Some custom ore was also run. The matte-fall was but 1.5 per cent., the matte containing 48 per cent. copper. A slag was produced having the composition, SiO_2, 38.5 per cent.; FeO, 30.2; CaO, 20.5; Cu, 0.286 per cent., together with 0.0043 oz. Au and 0.072 oz. Ag per ton, the slag making 86 per cent. of the total charge.

Smelter Practice at Great Falls, Mont.[2]—The reverberatory furnaces are 20 ft. wide by 125 ft. long. They were at first fired with coal of 25 per cent. ash, using a gas-producing fire-box. These furnaces smelted 225

[1] Report of Canadian Copper Corporation for 1915; *Eng. Min. Jour.*, **101**, 1074.
[2] *Eng. Min. Jour.*, **102**, 636.

tons per day with 44 per cent. of coal. The same coal, used in pulverized form, now smelts 500 tons of charge with 21 per cent. of coal.

Smelting at the Arizona Copper Co. Smelter.[1]—Descriptions of this reverberatory plant are to be found in Mineral Industry, **20**, 227; **23**, 224, 232; **24**, 221; also the smelter construction costs in **23**, 247. F. N. Flynn gives particulars of operation of the plant, situated on gently sloping ground 2 miles below Clifton, Ariz.

In the roasting department are eight 6-hearth Herreshoff furnaces, 21 ft. 7 in. in diam. For the upper hearths fire-brick are used. Hearths 2 and 3 on two furnaces are made of concrete, on hearths 4 and 5 concrete is preferred, while the lower one is formed of 2 in. of concrete. Reinforcing rods for them should be ½ in. in diam. For the hearths gravel-concrete and slag-concrete have been tried, the latter being the best. The slag-concrete mixture consists of 3 parts of very siliceous slag, crushed to pass ½-in. mesh, 3 parts of clean sand and 1 part of cement. The rabble-arms and central column of the furnaces are air-cooled.

The roaster charge has varied from ore, lime-rock and concentrate mixture with 19.2 per cent. sulphur and 10.7 per cent. copper, to all concentrates with 30.7 sulphur and 15.8 per cent. copper, with fuel requirements varying from 40 lb. of coal per ton of calcines to none when roasting all concentrate. From 7.5 to 17.4 per cent. sulphur was removed in roasting, the aim being to leave equal quantities of sulphur and copper in the calcine because of the oxidized ore used in the reverberatory fettling. Heavy crude oil was tried, inserting the oil burners at the third or fourth hearth, but by the time it ignited, the charge would be fusing in front of the burners. Outside fire-boxes are used, applied at the fifth hearth. Ignition takes place on the fourth hearth, and the temperature of the charge on the two lower hearths is 650° to 700° C. With but one reverberatory furnace running, each roaster is pushed to roast but 60 tons of calcine daily; with two, 80 tons. Less coal is needed at the lower output, and where this has been raised to a monthly average of 113 tons of calcine per furnace-day, the coal ratio becomes much higher. The furnace dampers are kept closed just to the point of smoking. The velocity of the escaping gases in the header flue is 6 to 7 ft. per sec., their temperature falling to 160° to 230° C. where they pass to the large dust-chamber. The chamber flue dust amounts to but 0.8 per cent.

Of the three 22 by 100-ft. reverberatories, one or at most two are operated, the third being in reserve. Furnaces Nos. 1 and 2 have hearths of crushed silica fused in on bottoms of broken quartz; No. 3 furnace is of crushed silica on a slag bottom. Fettling is done at the sides and across the fire end through 6-in. holes at 2-ft. centers; but these holes are being

[1] *Bull. Amer. Inst. Min. Eng.*, Sept., 1916.

changed to 8-in. to allow for the use of coarser material. The height of the crown of the reverberatory arch toward the fire end, 7 ft. 10 in., is satisfactory for burning small quantities of oil, but might be raised there to advantage for larger quantities. In a 16-months' campaign, when running one furnace, there was 16½ days lost time for repairs. The daily average tonnage of this campaign was 384.6 tons, the highest monthly average was 512.4 tons. Per ton of solid charge the average oil used was 0.744 bbl. and the lowest monthly result 0.653 bbl. Fifteen-ton charges of calcine at a temperature of 560° to 620° C. are dropped through one water-jacketed hole in the center of the roof from either of the two transverse charging tracks, but 90 per cent. of this is dropped from the back track. This "direct charge" constitutes 75 per cent. of the total solid charge. Bad furnace conditions result and floaters form if cold materials, such as crude ore, slag, lime-rock or siliceous ore, are dropped as direct charge without mixing well with hot calcine. Such mixing may be done in the calcines car, or better at the roasters. Calcine, made from concentrate or sulphide ore, smelts readily, whereas a mixture of crushed siliceous oxidized ore mixed with much lime-rock smelts slowly.

A daily average of 365 tons was smelted from calcined concentrate, while but 200 tons was put through on a charge made from a mixture of 70 per cent. sulphide concentrate; siliceous ore, 4.8; siliceous oxide ore, 12.9; and lime-rock, 11.6 per cent. The endeavor is to keep the sulphide material as high as 75 per cent. of the total bed mixture. The charges spread better when the furnace is nearly full of matte, also when the sulphur and copper in the calcine are equal. Fettling material, crushed to 2½ in., constitutes 25 per cent. of the total solid charge. Of this it is customary to feed about one-fourth, consisting of old smelter slag and converter slag skulls, along the sides toward the back at the fire-end, and half next to it, of the less siliceous ore, while toward the front the remainder is more siliceous, or even quartzose. The angle of repose of this 2½-in. fettling material is 45° above the slag line and 45° to 60° below it. Fine-crushed material works poorly for fettling; the less siliceous ore is best, except near the front. Pyrite at the front melts to a magnetic mush, but in the back half with siliceous ore melts well. The ideal fettling material is to be found in a coarse copper sulphide containing 5 to 10 per cent. sulphur. The fuel used is oil of 14° Bé. of a heating power of 10,000 Cal. It is pumped at 120 lb. pressure and delivered through steam heaters at a temperature of 77° C. to six burners, and atomized with converter air. The draft inside the furnace at the throat is 0.12 to 0.16 in. of water, in the header flue 0.50 in. The gases leave the furnace at a temperature of 980° to 1095° C. and the waste-heat boilers at 245° to 300° C., while in the flue connecting to the main stack it ranges from 205° to 278° C.

At these temperatures, the average velocity of the gases in the flue will be 10 ft. per sec. when running one furnace. An average analysis of the gas shows it to contain SO_2, 0.3 per cent.; CO_2, 5.9; O, 12.9; CO, 0.4; N, 80.5 per cent.; SO_3, not determined. When running one furnace, and using four or five of the waste-heat boilers, about 5 tons of dust is caught at the boilers monthly. At the end of the 2 years' operation about 100 tons of dust was removed from the main header flue. This dust contained Cu, 9.65 per cent. and free H_2SO_4, 3 per cent. The flue roof was originally made of No. 14 steel plate. After 8 months' service, holes were eaten in the plate, while all was pitted and nearly eaten through. Moist flue dust covered the inside surface of the roof, this deposit consisting principally of sulphides of iron and copper. For repair, concrete slabs, reinforced with wire netting, were laid on top of the plates, the joints being filled with asphalt. This covering lasted 2 years. The corrosive action of the gases on the plates was thus arrested during 10 months of operation; but during an idleness of 5 months, due to labor trouble, the plate corroded completely. The old flue walls were made of tile; but these broke, and the new walls have been made of brick laid in slime mortar.

Converter slag is poured through the back wall of the furnace at the center by a launder. Magnetite builds up under the launder-discharge, but at either side at the bridge, fettling is needed. All the iron present in converter slag, other than that which is in magnetic state, is available for flux. It is true this slag sinks below the highly siliceous slag above, but all is violently agitated, when the calcine charge is dropped as the result of that charge releasing gases due to reactions. On several occasions two furnaces, having identical charges, have been run, one receiving all the converter slag, the other the full quantity of limestone needed for fluxing, showing that the excess iron in the converter slag performed its full fluxing duty.

The converting department has five 12-ft. Great Falls type converters, the shells lined with magnesite brick. For these have been provided four converter stands. Two of these stands are regularly used. Air at 13 lb. pressure is supplied by two out of three Nordberg blowing-engines.

For protection of the brick, the practice is to renew a magnetite coating whenever the lines of the brickwork are seen through the thin coating remaining. When coated, the loose magnetite and copper mush is dumped upon the floor; later it is charged in small quantities with the regular charges; when coated, blowing proceeds using a large excess of silica. To granulate the final slag on the copper finish some 350 lb. of 80 per cent. silica ore is used; this ensures the removal of the last traces of iron. When converting matte of over 40 per cent. copper, but little of the cold matte shells or cleanings from the floor can be used; but with lower-grade matte the matte-shells, converter flue dust, and converter by-products can be returned to the converter.

Molten copper is transferred to the two straight-line casting machines in cast-steel ladles lined with fines screened from ores used for converter fluxing. Each casting machine has 39 moulds made of converter copper. A 1¼-in. splash-plate covers half the bottom of the mould and will last for the casting of 73 tons of copper. Bars weigh 240 lb. each, and a charge of 7 tons can be cast in 35 min. The blowing is done to a gas finish of 99.6 per cent. copper.

Furnace Reactions and Products

Flowing Temperatures of Mattes.[1]—G. A. Guess and F. E. Lathe have investigated the flowing temperatures both of copper and of copper-nickel mattes, thinking that if copper-nickel matte became fluid at a considerably lower temperature than ordinary copper matte, it would explain the difficulty of pyritically smelting copper-nickel ores. They found that copper-nickel mattes appear to have a flowing temperature of but 30° to 50° C. below copper mattes usual in the blast furnace, not enough to explain failures in treating copper-nickel ores. The flowing temperature ranged around 900° to 1000° C.

Heat Reactions in Pyritic Smelting.[2]—Robert C. Sticht discusses the question of the heat developed in pyritic smelting at Mt. Lyell. Mt. Lyell pyrite contains 46 per cent. sulphur, the North Mt. Lyell ore but 7.5 per cent., and the ordinary furnace mixture of the two 30 per cent. Of this sulphur 36 to 38 per cent. is burned at the furnace focus, 2 per cent. goes into the matte and the remainder is simply volatilized as elemental sulphur, which is burned to no purpose when it meets the air above the charge. Thus it will be seen that the heat evolved from the burning of the sulphur is less than if only the first equivalent of sulphur had been expelled. Since 95 per cent. of the iron present is burned to ferrous oxide its influence is to be added. As a result of this shortage of heat it has not been possible to dispense with coke entirely and 4 to 5 per cent. is used. It had been thought that as the smelting column was raised to 18 ft. from the original height of 12 ft. greater economy of coke would be attained, and indeed this has contributed. On the other hand, about the time this change was effected, the iron and sulphur in the ore charge began to decrease, and the zinc and lead increased, so that, in place of lowering the coke percentage, it was necessary to raise it. We

[1] *Bull. Amer. Inst. Min. Eng.*, June, 1916, 1067.
[2] *Proc. Aust. Inst. Min. Eng.*, No. 19, 1915; *Min. Eng. World*, **44**, 698.

may add that no practical way has been yet devised to increase the pressure upon the escaping sulphur vapor in order to more effectively burn it.

The blast pressure in the early experience of Mt. Lyell was 18 oz.; at present as much as 96 oz. or 6 lb. per sq. in. has been carried. Since a converter can be blown successfully at 8 lb., this pressure-difference is disappearing.

In operation the furnace crew strives to feed fines with coarse ore so as to maintain the charge as open as possible. Limestone also increases the openness, but is rather sparingly applied for that purpose. Slag charges, using slag and coke together, are seldom used. Care in feeding from the charging plate is the rule, and dumping in mass is not permitted. The slag, of 36 to 38 per cent. SiO_2, is irony, and hot enough to run through the main forehearth and three or four smaller ones in series. The fall in temperature in going through the forehearths is 80 to 90° C., the slag still being bright, smokeless and free-flowing. It varies from 0.25 to 0.5 per cent., according to the grade of the matte. The sulphur in the slag is low, being not more than 0.3 to 0.5 per cent. The grade of matte desired is 45 to 50 per cent. in copper, as being well suited to converter operations, and to maintain this grade, charges may be altered several times per day. The charge is down in a couple of hours, and the matte being assayed, further charges to obtain the correct grade may be made. It is found that free silica, rather than that combined with bases, is a potent factor. Its heat of combination is what makes it so important. In changing the charge it is preferred to vary the silica rather than the pyrites since the action is more decisive. Accordingly a typical charge would be Mt. Lyell pyrite 2240 lb., limestone 250 lb., both being constant while the North Lyell silica-carrying ore varies from 1000 to 1700 lb., the coke being correspondingly increased from 160 to 250 lb. Converter slag, 50 to 550 lb. is also put in. The daily output is 1000 to 1200 long tons having an average of 2½ per cent. Cu and yielding a matte of 40 to 50 per cent. Cu.

Mr. Sticht thinks there is hope for cokeless smelting, especially if the heat reactions of sulphur and silica are better utilized by more efficient furnace construction.

Blast Furnaces

Blast Furnaces of the Union Minière du Haut Katanga.[1]—These recent blast furnaces, 44 in. by 20 ft., Fig. 1, are manufactured by the Traylor Eng. & Mfg. Co., Allentown, Pa. They are the largest black-copper blast furnaces ever built, and are for the reduction of the oxidized ores of the above-named company at Lubumbashi near Elizabethville, Belgian

[1] *Eng. Min. Jour.*, **102**, 658.

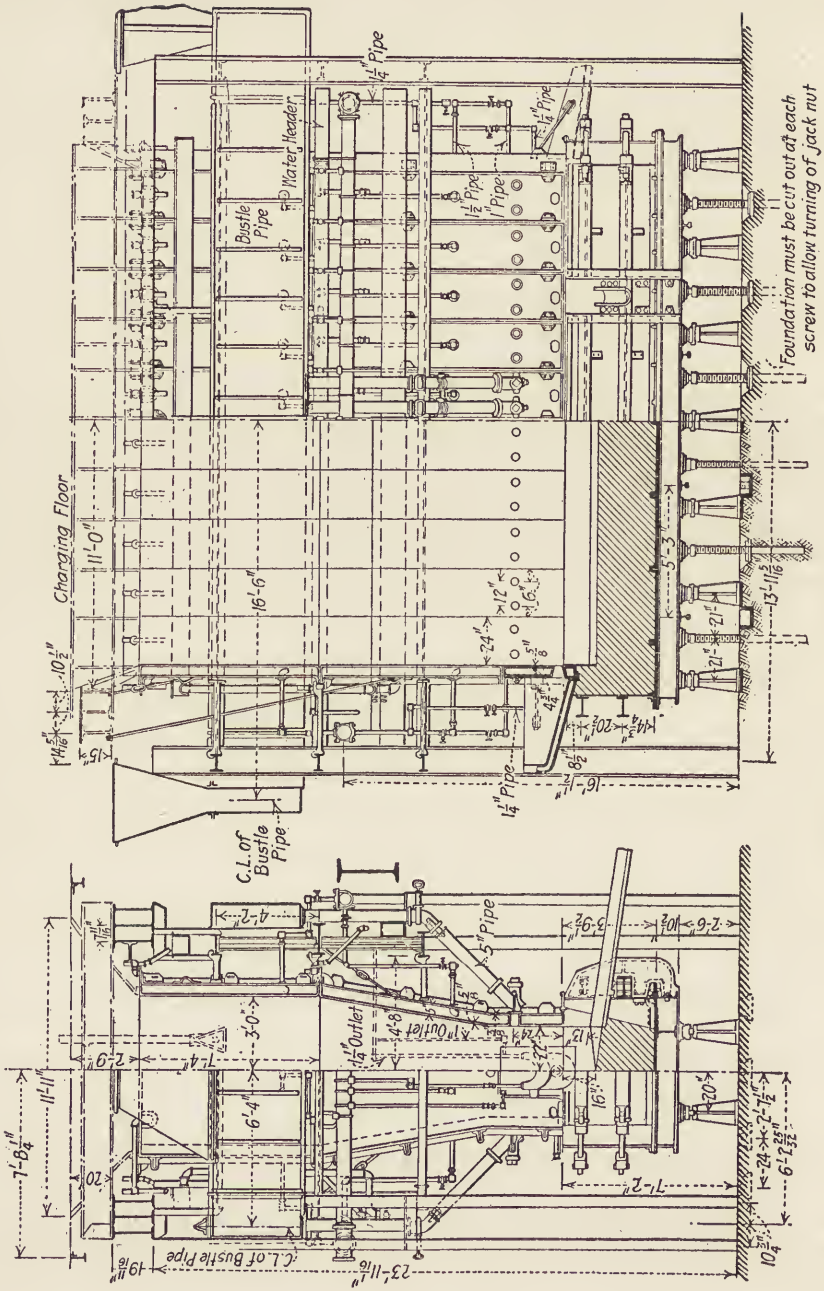

Fig. 1.—Blast furnaces of the Union Minière du Haut Katanga.

Congo. Four have been sent to the company and two more are building for them.

The furnaces have two tiers of jackets. The lower side jackets, 10 ft. high by 2 ft. wide, are boshed 14 in. The upper jackets, of the same width, are 7 ft. 4 in. high. The end jackets are vertical. The tuyères, 20 per side, are 4 in. in diam. From the center line of the tuyères to the feed-floor is 18 ft., which, with a 14-in. side bosh, should insure good reduction. At one end is a trapped slag-spout for continuous flow of slag; at the other end is a slag-spout to be used in case the slag has to be tapped off. At one side, and nearer the same end, is the bullion spout for periodically removing the metal from the interior crucible. To the top of the hearth is

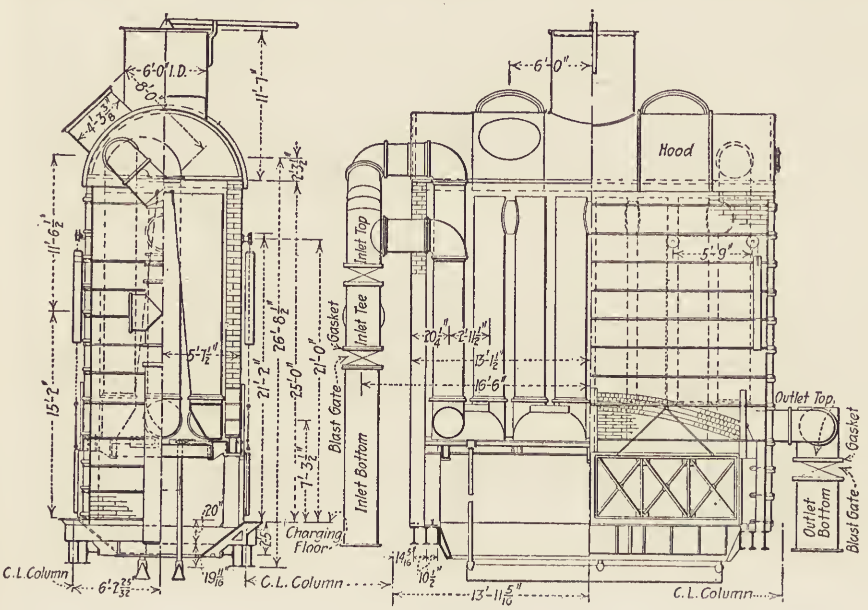

Fig. 2.—Giroux hot top.

7 ft. 2 in., so that there is sufficient room for a forehearth beneath the trapped slag-spout. The bustle-pipe is rectangular in section in order to save building space.

The furnace is furnished with a Giroux hot top intended for heating the blast-air as shown in Fig. 2. The course of the air is as follows: It enters at the inlet bottom, and at the inlet tee goes by the side outlet direct to the bustle pipe, or entering the inlet top is branched to the double row of heating pipes within the furnace top, going through them in series, top and bottom. Arriving at the outlet top it enters the outlet bottom through the blast gate, and so to the bustle pipe by a reducer as seen in the elevation of the furnace, Fig. 2. The outlet is larger than the inlet pipe to allow for the increased volume of the air when heated.

The company turned out 25,000 tons of copper in 1916 against 14,190 in the preceding year.

Feeding Blast Furnaces.[1]—Robert C. Sticht says that the feeding of the blast furnace by shooting charges into it as is commonly done is crude, giving irregular furnacing, and effects but a small saving in labor over a suitable modification, such as he has devised at Mt. Lyell. He shows (and rightly so) that sudden and careless dropping of the charge causes irregular rising of the blast, producing hot spots, blow-holes, and eventual hanging up of the furnace, which must be barred off for a new campaign. In proper operation the gases must issue evenly over the top of the charge, with but slightly more coming up along the walls. The charge, when first put in, is of course black for a while, then becomes of a low red, but there is no appearance of high incandescence. The general temperature should only be high enough to ignite the escaping sulphur. There should be no blow-holes. Dead glowing red places indicate formation of accretions or wall-crusts. They tend to close the throat. To remove them some pyrite is fed there and the siliceous ore kept off. For blow-holes, siliceous ore, slag or limestone are put in. When the throat is working properly there is the continuous crackling noise, due to the decrepitation of the pyrite.

The feeding at Mt. Lyell is done on the full length of the long sides of the furnace, the charge being first dumped from end-discharging hand-cars upon the charge-plates, which slightly overhang the side walls of the shaft. The narrow ridge of charge is thus as long as the opening. The charge, thus placed, is pushed gradually into the furnace by a line of hinged plates inclined forward and parallel to the furnace, fixed in a frame embracing both sides of the furnace, and actuated by an hydraulic cylinder, so that the two sides are fed alternately. Being hinged, the pusher-plates on the back stroke ride over any materials that lie scattered upon the charge-plates. The charge may be so placed as to suit the needs of any part of the furnace, and can be further adjusted by the feeders, who shovel it to the right or left. The materials fall almost vertically from the edge of the charge-plate, the fines closer to the wall. The overhang of the plate can also be readily varied. Observation of the condition of the furnace is made through openings in the end doors. Materials of the charge are fed as follows: The coke is first put in, then all the pyrites, the siliceous ore, the limestone and finally the slag. Briquetted or wet mixed flue dust and barren silica are put in at intervals as required.

[1] *Proc. Aust. Inst. Min. Eng.*, 1916; *Met. Chem. Eng.*, **14**, 537.

Chrome-ore Tapping Blocks.[1]—B. Magnus gives the advantages of these tapping blocks for the forehearths of blast furnaces producing copper matte. The chrome ore must be of the highest grade and in the form of an 18-in. cubic block with a 1-in. tap-hole. The breast needed no renewal for weeks at a time, while a water-cooled cast-iron tap-jacket would last no more than a month on low-grade matte. Besides this there was no water about to cause the matte to explode, and no water-supply was needed.

Slag Lining for Launders.[2]—W. A. Leddell describes his slag liner, 12 by 12 by 2 in. thick, with two upturned edges to line a 12-in. launder. These are cast from molten slag in a two-part mould set vertically. The blocks are reinforced by poultry netting, which is bent to cover the interior surface of the mould. The top of the mould is covered with a hole which serves as a short riser. The blocks, as formed, are layered up with sand so as to cool slowly to temper them. These liners several times outlast cast-iron liners in acid waters, or 2-in. plank. Slag lining has also served well for chute bottoms for finer material.

Reverberatory Furnaces

Coal-dust-fired Reverberatory Furnaces.[3]—We give herewith the principal dimensions of typical coal-dust-fired reverberatories.

Number.	Length.	Width.	Maximum Height of Arch above Skimplate.	
			Firing End.	Flue End.
1	112 ft.	19 ft.	6 ft. 8 in.	4 ft. 8 in.
2	143 ft.	25 ft.	7 ft. 6 in.	4 ft. 6 in.
3	112 ft.	19 ft.	....	....
4	125 ft.	22 ft.	5 ft. 6 in.	4 ft. 10 in.

Plant No. 1 is at Copper Cliff, Ont.; No. 2 at Anaconda, Mont.; No. 3 at Garfield, Utah; No. 4 at Great Falls, Mont.

While feeding along the walls at 2-ft. intervals is now common, in one instance the charge has been introduced through two rows of hoppers 6 ft. 6 in. from the side walls. Side charging is generally thought best, since it protects the walls, and the charging being a little at a time, a more nearly uniform temperature can be maintained in the furnace. The furnaceman, looking through the peep hole at each charging pipe, can

[1] *Eng. Min. Jour.*, **101**, 778.
[2] *Eng. Min. Jour.*, **102**, 644.
[3] Paper at 2d Pan-American Sci. Cong.; *Eng. Min. Jour.*, **101**, 305; *Bull. Amer. Inst. Min. Eng.*, Feb., 1915; May, 1915.

observe the height of the ore lying against the wall, and can let down more ore as needed by opening the sliding gate of the feed-pipe.

The slag is often tapped at 2- to 3-hr. intervals; however, at Anaconda, it is run off continuously. Any unfused floating material or scum, which comes to the skimming hole, is fluxed by small additions of limestone rabbled into it three or four times per shift. Thus no prills of matte are lost as would happen were unfused material allowed to escape. Unless there is an excess of iron in the slag, the bath of matte is smaller in quantity than in former practice. Due to side charging, the matte tap-hole has been moved near the front end of the furnace when side banking does not interfere. Combustion is controlled to make it perfect, the gases then carrying less than 0.5 per cent. oxygen and of carbon monoxide respectively. Cases occur when there is not even this excess.

Furnace repairs are less costly with coal-dust firing. The roof at the hottest region burns out more slowly, the tonnage smelted is greater, and the repair cost per ton of ore is less.

Chrome-ore Reverberatory Lining.[1]—Edgar Hall describes his experience with this material in a 40 by 15-ft. furnace, when treating a charge producing a corrosive slag of SiO_2, 32; ZnO, 25; PbO, 5; FeO, 20 per cent. and with a 3 per cent. matte-fall. The chromite iron ore cost $25 per long ton. Before the final lining was adopted magnesia bricks were tried, but did not last well. Bauxite bricks were, however, successful.

The 10-in. bottom was laid dry upon an infusible layer of fragments of chromite mixed with clear zinc blende. This bottom was laid dry with closely fitting lumps of the chromite iron ore, and any openings filled with the blende-chromite mixture. The side walls, 16 in. thick, were also closely fitting blocks of chromite to above the slag line, and above that of fire-brick. The sides and bottom continued in use and never moved, lasting until the furnace was pulled down years later.

After a few weeks a chromite sand layer, due to wear from the lining, gradually accumulated between the slag and the matte. So long as the charge is well oxidized and the matte is clean the slag separates well, and the sand layer can be skimmed out free from globules of matte. But, if the ore has been poorly roasted, zinc goes into the matte and this light zinc matte becomes intimately mixed with the sand, making a horrible mixture, infusible except on prolonged firing, and carrying 200 oz. silver per ton.

The treatment of the mixture, as well as the chrome bottoms, when the furnace was torn down, seemed to be a difficult problem, which was solved only by sending the material to the lead blast furnace. Here,

[1] *Eng. Min. Jour.*, **101**, 267.

crushed fine, it presented no difficulty in treatment, due to the reducing action of the furnace.

Seasoning a Reverberatory Furnace.[1]—E. C. King describes the method followed in drying out and heating up the brickwork of a 100-ft. reverberatory furnace. The gases from the fettling holes at the front of an oil-fired reverberatory operating at 1200° C., drawn by a 36-in. suction fan through 10-in. pipe, were delivered at the rate of 3000 cu. ft. per min., and at a temperature of 240° C., through the center firing hole of the furnace to be seasoned. The radical drop in temperature to 240° C. was due to radiation from the 10-in. pipe, which was 90 ft. long. For the first 12 hr. the gases were made cooler by admission of air at the intake; in 24 hr. the brickwork was warming up, and in 48 hr. it was beyond the point of sensitiveness. The four oil-blast pipes were then put in, bringing the furnace to operation in 4 days 2 hr.

Converters and Converting

Moving a 20-ft. Converter.[2]—During reconstruction in the converter department at Great Falls in 1913, the converter, weighing 210 tons, had to be transferred to the opposite side of the converter aisle and turned 180° in so doing.

Small Pierce-Smith Converter.[3]—At the Naltagua smeltery in Central Chile there is employed this type of basic-lined converter, 10 ft. in diam. by 14 ft. 7 in. long. None so small is used in the United States, where the standard size is 10 by 25 ft., though shells 12 ft. in diam. by 37 ft. 2 in. in length have been used.

Smelteries

Improvements at Anaconda.[4]—The Anaconda Copper Mining Co. has instituted improvements aggregating $6,000,000, the funds having been raised by the issue of a 2-year 5 per cent. note issue. Estimates of the net earnings of the company for 1915 are $16,000,000. The improved processes were put into operation early this year, and by it the company added about 50,000,000 lb. copper to their output without increasing tonnage or the grade of ore mined. Approximately 40,000,000 lb. of this increased production has been made without adding to the cost per ton of ore treated, the increased cost due to introducing flotation having been offset by the decreased smelting cost of 50 cts. per ton. Thus the cost of the improvements has been covered in less than a year. Had these improvements been put in practice in 1913, the results on a 14-ct.

[1] *Eng. Min. Jour.*, **101**, 721.
[2] *Eng. Min. Jour.*, **101**, 396.
[3] *Eng. Min. Jour.*, **102**, 680.
[4] Annual Report, 1915.

copper would have added $7,000,000 to the income of the company. Due to the introduction of the flotation method of concentration, the Washoe works are concentrating 15,000 tons of milling ore daily as against a former output of 12,000 tons, and have increased recoveries in the concentrates, formerly 82 per cent., to 96 per cent.[1] On a 3 per cent. ore this is equivalent to 8.4 lb. copper per ton of milling ore. From a daily output of 15,000 tons of this ore are yielded 3000 tons of slimes. To treat this, and 1000 tons taken from the slime ponds, a 4000-ton flotation plant has been created, which will add 900,000 lb. copper monthly to the output of the works. Since the works began operations, some 20 million tons of sands have been accumulated, which carry 11 lb. copper per ton. This vast amount is treated by leaching in a plant of 2000 tons daily capacity with a recovery of 9.2 lb. copper per ton. The greater tonnage of concentrates produced has necessitated increased roasting capacity, and to meet this, plant No. 2, containing 28 25-ft. MacDougall-Wedge roasters has been built; also a Cottrell system of fume precipitation. To supply sulphuric acid for the plant a 100-ton chamber-process acid plant has been erected. This plant has been enlarged to produce 150 tons daily of 60° Bé. acid, the enlargement being due to the growing demand for sulphuric acid in this region. The works has now eight reverberatories of a capacity of 650 tons each and one at the converter building 150 ft. long for smelting converter slags and by-products, by which a saving of $500 daily will be effected. By these changes smelting costs have been reduced 50 cts. per ton over the older practice with shorter furnaces. The installation of the five Great Falls type 20-ft. converters (making seven in all) has increased the converter capacity from 19,000,000 to 24,000,000 lb. monthly, reducing operating costs $1 per ton.

Improvements at Great Falls.[2]—The Anaconda Copper Mining Co. at its Great Falls works has built a modern electrolytic refinery for 180,000,000 lb. copper annually, where the cost of refining will be $3 less per ton than at the old refinery. Since the concentrator at the Anaconda works can supply concentrates enough for both of the company's smelting plants, the concentrating department at Great Falls has been abandoned, thus affecting a saving by transporting concentrates from Anaconda to Great Falls instead of crude ore from Butte to Great Falls. The further changes at Great Falls have been the remodelling of the roasting department, rebuilding the reverberatory furnaces and equipping them for coal-dust firing, and completing the installation of the 20-ft. Great Falls type converters.

[1] While the recoveries hold as regards the concentrated ore, the further operations of roasting, smelting and converting give a yield of 77 per cent. and a total recovery of 90 per cent.
[2] Annual Report, 1915.

The Tacoma Smeltery.[1]—This works treats ores from British Columbia, from Chusan, China, and oxidized ores from South America, though foreign shipments have been kept back by high freight rates and lack of vessels. The ores vary from 15 to 20 per cent. copper, while high-grade ore from the Kennecott mines, Alaska, averages 70 per cent. copper.

In 1915 the plant had two blast furnaces, and a converter capacity of 6000 to 7000 tons copper monthly, also an electrolytic refinery of 2000 tons per month. During 1916 there has been added an oil-fired reverberatory furnace, 24 by 136 ft. hearth dimensions, Herreshoff roasters for fine ores, and Pierce-Smith converters, now seven in all. A new refinery of over 3000 tons monthly has been added, a new power plant built, and a Cottrell treater installed. A 550-ft. stack of 25-ft. internal diameter at the top and 38-ft. at the bottom has been built of second-class paving brick which are acid-proof. A matte of 60 per cent. copper is produced.

Garfield (Utah) Smeltery.[2]—The combined capacity of the two sampling mills is 2400 tons daily. Concentrates are shovel-sampled, the rejects being at once carried by belt conveyors to bins holding 25,000 tons.

There are now four blast furnaces, 42 in. by 20 ft. long at the tuyères, using 20,000 cu. ft. of air per min. per furnace at 40 oz. pressure, the ore column being 15½ ft. high. Formerly, with a column of 12 to 14 ft., the furnace was fed through chutes delivering below the feed-floor level. At present but two furnaces are in operation, due to increased use of flotation concentrates, which must be smelted in the reverberatories. It is even planned that the coarse ore shall be crushed and added to the reverberatory charge, thus doing away with the blast furnace.

There are 34 multiple-hearth roasters; 16 are six-hearth MacDougalls, 18 ft. in diam.; 14 are six-hearth MacDougalls, 19½ ft. in diam.; and 4 are seven-hearth Herreshoff furnaces, 19½ ft. in diam.

There are six reverberatory furnaces, four being 112 by 19 ft. hearth dimensions, one 112 by 20½ ft. and one of 120 by 20½ ft. Each is putting through 460 tons daily. In charging, both central and side charging have been tried. The best results have been obtained by a combination of the two methods, and this will soon apply to all the furnaces. The plant is equipped for oil-firing, yet that too has been given up in favor of the cheaper coal-dust firing. Combustion is so complete, that the furnace clears rapidly as the flue end is approached. Ash causes no trouble, either by blanketing the charge or later by clogging the waste-heat boilers. The coal consumption is 14 per cent. To avoid explosions of the coal dust when grinding or feeding it, care is taken to keep it in small units, and to watch out for incipient fires, and to extinguish them promptly.

[1] *Eng. Min. Jour.*, **102**, 298.
[2] *Min. Sci. Press*, **113**, 55.

Having three Pierce-Smith converters, 10 by 24 ft., in operation each converter puts through daily 120 tons of matte and 30 tons of siliceous Tintic ore, yielding 60 tons of blister copper of 99.1 per cent. Cu.

Consolidated Arizona Smelting Co. Smeltery.[1]—This plant is located at Humboldt, Ariz., and produces 500,000 lb. of blister copper monthly from ore of which 66 to 75 per cent. is company ore, the rest custom ores.

The equipment comprises one seven-hearth Wedge roaster, 21½ ft. in diam., fitted with auxiliary oil burners, two reverberatory furnaces, respectively 19 by 60 ft. and 19 by 100 ft. hearth dimensions; also two barrel-type basic-lined converters 9½ ft. in diam. The table herewith gives the average analysis of the company materials treated:

	Ounces per Ton.		Per Cent.				
	Au.	Ag.	Cu.	Insol.	Fe.	CaO.	S.
General mill concentrate	0.09	3.04	9.52	16.5	30.0	....	....
Smelting ore	0.04	1.50	3.70	46.0	20.0	1.3	22.0
Roaster feed	....	....	6.00	20.0	30.0	1.4	20.0
Calcine	....	....	6.20	23.5	35.5	1.4	9.0
Reverberatory slag	....	....	0.35	38.0	38.0	0.8	....
Matte	....	....	35.00	....	....	....	....
Blister copper	1.00	28.00	99.10	....	....	....	....

Much of the custom ore is a copper-bearing specular hematite of 48 per cent. Fe, 10 per cent. SiO_2. For converter flux and fettling material a highly siliceous copper ore is used. This contains 3.8 per cent. Cu and 70 to 80 per cent. insoluble matter, the copper minerals being more or less oxidized, and so not suited to flotation. It will be seen that all materials for smelting contain copper, thus adding to profitable operation.

The feed to the roasters consists of 600 lb. smelting ore, 3400 lb. specular iron and 6000 lb. general mill concentrate of the composition just given. Some 75 per cent. of the mill concentrate is a flotation product, 60 per cent. of which is finer than 200-mesh, so that in roasting there is an excessive dust loss, and that too in spite of the smelting and iron ore being crushed to ½-in. mesh only. The roaster puts through 110 tons daily; the sulphur in the feed, varying from 17 per cent. to 20 per cent. as above, is generally self-roasting and the auxiliary oil-feed is only used occasionally.

The reverberatory charge to the 19- by 60-ft. furnace consists of the calcines from the above 10,000 lb. of charge, 1500 lb. of converter slag, 2500 lb. of iron ore and 1500 lb. of mill concentrates or a total of 15,500 lb., being with fettling material, a daily capacity of 165 to 175 tons. With such considerable additions of cold material the furnace works slower and uses more fuel-oil than when the hot calcine and molten

[1] *Met. Chem. Eng.*, **14**, 33.

converter slag can be used. It has two 350-hp. Sterling waste-heat boilers. The average grade of furnace charge and products is shown in the table above.

The larger 19- by 100-ft. reverberatory furnace has a continuous hopper across the fire-end and along the side walls, and from the hopper a blended fettling material will be let down by pipes to the walls. The charge consists of 30 per cent. calcine with 70 per cent. of cold charge, but this is modified as roasting capacity increases. This furnace is figured for 450 tons eventual capacity, with a monthly production of 1,000,000 lb. copper.

Converter capacity is so in excess that blowing is intermittent; still this has caused no serious injury as might have been expected from expansion and contraction of the brick lining. When a new lining has been put in, a number of charges are blown at short intervals in order to saturate and bond the brick. Thus seasoned, intervals of 7 or 8 hr. are permissible between blows, and even 30-hr. intervals have been tried. The lining can be kept warm by adding fuel within the converter. While magnesite brick has done well it is in contemplation to try a less expensive lining of magnesite cemented with water-glass or magnesium sulphate.

Grand Forks Smeltery.[1]—This works handled in the fiscal year ending June 30, 1916, 500,000 tons of siliceous ore containing 1 per cent. copper. For the first 6 months of the fiscal year the costs were as low as $1.233 per ton. Higher wages added 1.7 cts., coke 1.3 cts., and Anyox matte 0.7 ct. per ton. With eight furnaces in blast there were 195 to 200 men on the payroll.

The Anyox Smeltery.[2]—Due to strikes and other delays, an average of 3.2 furnaces out of four were in blast, which, in the year ending June 30, yielded 250,000 tons of molten material.

Fig. 3 gives the two elevations of the new No. 4 blast furnace, 54 in. by 30 ft., with plunger feed arrangements. There are three tiers of jackets, respectively 10 ft. 6 in., 6 ft. 8 in., and 5 ft. 2 in. high, with a cast-iron hopper-top 2 ft. 7½ in. in depth. The distance from the center line of the tuyères to the sole of the plunger feed plate is 20 ft. 6 in., while between floors is 26 ft., an unusual depth for a matting furnace. The side-jackets, all but the center one, are 7 ft. 6 in. wide, and have each four 5-in. tuyères set at 11-in. centers, so that there are 27 tuyères per side. The hearth-plate is water-cooled and carried on short columns. On this is built the crucible-bottom, sloping to the syphon-tap at the middle of the side. The crucibles can be drained by a tap-hole on the opposite side. At the charge-floor are six fixed plunger-feed hoppers on each side into which are dumped the contents of the charge-cars. When the furnace is to

[1] *Min. Sci. Press*, **113**, 777; Report of Granby Cons. M. S. & P. Co., June 30, 1916.
[2] *Eng. Min. Jour.*, **101**, 270; **102**, 658; Report Granby Cons. M. S. & P. Co., June 30, 1916; *Min. Sci. Press*, **113**, 777.

be fed, the valves controlling the hydraulic actuating cylinders are opened and a plunger, called a plow, moves forward through the hoppers, pushing

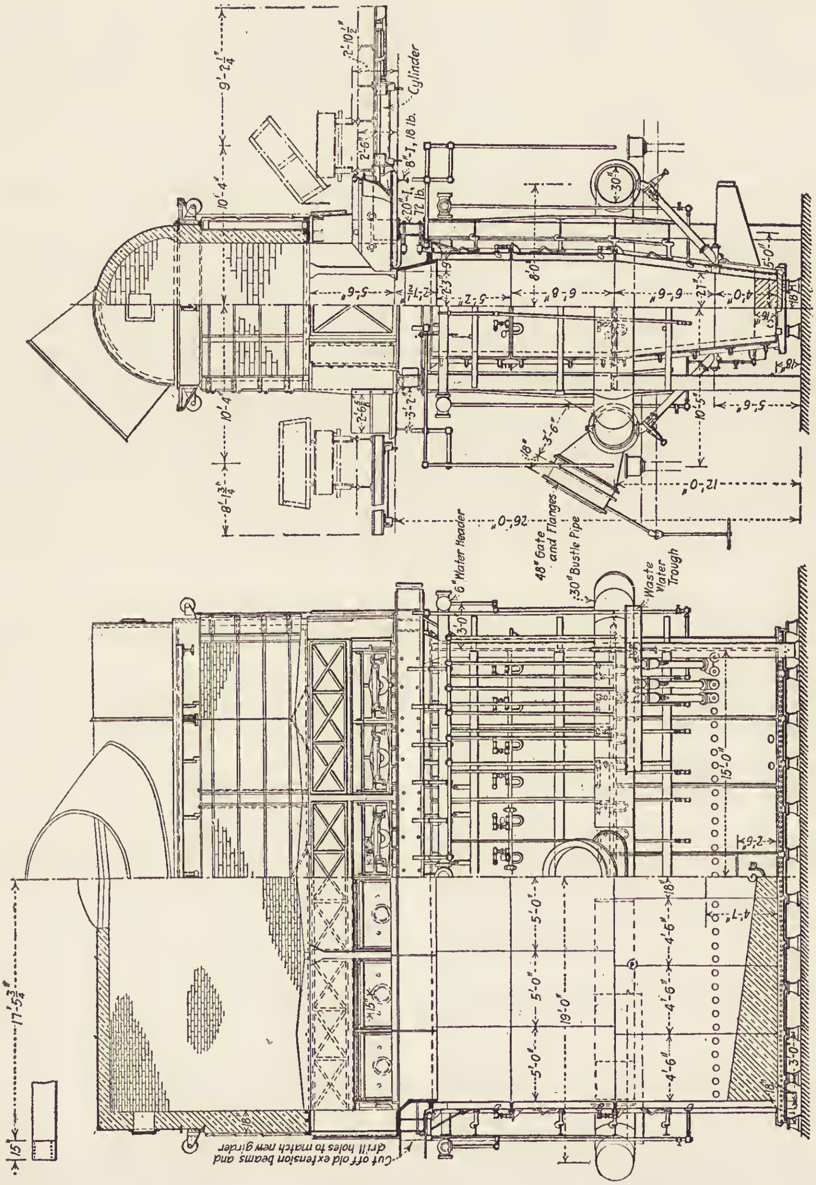

FIG. 3.—Copper-matting furnace, arranged for plunger feeding.

the charge in the furnace. As this movement is slow or fast, so the charge may fall at the center line or be thrown against the opposite wall of the furnace. The scheme has proven to be quite satisfactory; in fact it is claimed that the charge can be so made to fall as to jar off or sweep down accretions that may form upon the side walls. The furnace top is of brick and the gases are removed by a liberal-sized gooseneck off-take.

The slag is allowed to collect in the crucible until it is seen to be about to enter the tuyères, when it is tapped. A large flow may then keep up for 3 or 4 hr. before stopping to accumulate a fresh supply. This No. 4 furnace, having a shaft-depth 5 ft. greater than the original three, had by the end of June been in operation 10½ months. While with this greater height no gain was noted in the grade of the matte, in increased tonnage or in percentage of coke used, there is some gain in the length of a run, and in decreased crust-formation, due to increased drop of the charge. It is concluded that pyritic smelting with low coke and no fluxes can not be done constantly. The proportion of free silica is low; hence there is little exothermic heat due to its uniting with bases. Alumina is also high. In average practice it is necessary to use fairly high coke and limestone as flux. The ores smelted vary greatly in silica content from lot to lot, and this has created a tendency to uneven running. It is hoped that as the mines are developed, so that ores can be bedded, the making of a converter grade of matte in the first smelting may eventually be accomplished. At present, this can not be done, as the degree of oxidation is small, and the matte-fall from the ore smelting is too great for the converters to handle. Therefore, throughout the year three furnaces were operated smelting green ore, while the fourth was used for regrading matte. The better way would be to take all matte straight to the converters, irrespective of grade and convert direct; but this is not possible, due to lack of converter capacity.

The quantity of ore per furnace-day has increased from 630 to 692 tons, or for total charge, from 846 to 929 tons. Toward the end of the year the furnaces showed a record of as high as 1200 tons for several days together, and one of the furnaces has put through 1273 tons in 24 hr., or 9 tons per sq. ft. of hearth area.

There is 46,480 tons of flue dust stored. For agglomerating this a reverberatory furnace has been provided, which will also sinter converter slag and matte.

In the fiscal year the cost of smelting and converting was $1.804, being 73 cts. less than the year before. With the rise in the price of copper, wages have been increased, adding 4.57 cts. to the cost per ton of ore. In re-grading or concentrating the first matte, some 20,000 tons of barren quartz has been used, adding 68 cts. to the costs per ton of ore. With the opening of the Maple Bay properties nearby, it is hoped to substitute metal-bearing quartz. Lime flux has added 15.2 cts. to the costs. Due to shortage of power at Anyox, 21,428 tons of matte has been sent to the Grand Forks plant of the company for conversion into blister copper at an increased cost, due to freight, of 2 cts. per ton of ore. Coke, more costly than hitherto, added 1 ct. and all supplies going up 10 per cent. have added 4 cts. These seriously increased costs make a total of 33.5 cts. per ton of ore.

Humboldt Smeltery.[1]—This plant of the Consolidated Arizona Smelting Co. has two oil-fired reverberatories, respectively 100 by 19 ft. and 60 by 19 ft. hearth dimensions, connected to waste-heat boilers. The two converters, basic-lined, each 9 ft. by 7 ft. 6 in., are served by a 40-ton Whiting electric crane. It is proposed to increase the equipment by the addition of another reverberatory furnace, two Wedge roasters and a blast furnace.

Of the 125 tons of concentrates treated daily, 70 to 80 tons are from the mill of the company. We add to this 350 tons of smelting ores, 200 tons being custom ores. From 350 tons of company ore are yielded 70 to 83 tons already mentioned; by weight the table and flotation concentrates are equal, but in the recovery of the copper, the table yields 30 per cent., the flotation machine 70 per cent. The united product will average Cu, 9.53 per cent. with Au, 0.1 oz. and Ag, 3.0 oz. per ton. The flotation product is higher in copper, going Cu, 14.24 per cent. and carrying Au, 0.1 oz. and Ag, 3.8 oz. per ton.

The matte produced runs of 26 to 30 per cent. in copper; the slag contains SiO_2, 39 per cent.; Fe, 39.9; Al_2O_3, 4 to 5 and Cu, 0.35 per cent.

The Calumet and Arizona Smeltery.[2]—It comprises blast furnace, roaster, reverberatory and converter departments, with a sulphuric acid plant addition nearing completion. This smeltery treats about 2427 tons daily from the company's mines at Bisbee and 725 tons of custom ores. The production of blister copper, shipped to New Jersey for refining, is about 125 tons daily. Typical sulphide ores, constituting 50 per cent. of all treated, have the following analyses: Cu, 3.82 to 4.77 per cent.; S, 24.8 to 30.9; Fe, 25.4 to 30.9; SiO_2, 15.2 to 31.1 per cent. Oxidized ores carry Cu, 4.75 to 5.38 per cent.; S, 1.2 to 8.2; Fe, 21.3 to 25.6; SiO_2, 15.9 to 31 per cent. About 280 tons of siliceous custom ores average Cu, 2.15 per cent.; S, 32; Fe, 5.8 and SiO_2, 75.3 per cent.

Ores are sampled, then bedded by the Messiter system. Three of the beds of 21,000 tons are for fine ore for roasting; three beds, holding together 30,000 tons, are for coarse ore smelting.

The roaster plant consists of twelve 21½-ft. Herreshoff roasters, with twelve more under construction. Roasting ore from the beds discharges

[1] *Min. Eng. World*, **44,** 1133; Mineral Industry, **24,** 221.
[2] Booklet of Company, Sept., 1916; *Eng. Min. Jour.*, **102,** 663; *Met. Chem. Eng.*, **15,** 167; *Bull. Amer. Inst. Min. Eng.*, Aug., 1916, 1264; Mineral Industry, **23,** 242; **24,** 222.

into a 90-ton feed-bin for each roaster. The calcines are taken to the reverberatories in 20-ton electrically operated cars. The roasters treat 96.4 tons daily, averaging 26.9 per cent. sulphur, which is roasted down to 10 per cent. Each requires 66,000 cu. ft. of air per min., giving 4 per cent. of SO_2 in the escaping gases. The calcines and flue dust total 80.5 tons daily.

There are two 48-in. by 40-ft. blast furnaces. An end elevation and section of the blast-furnace building is shown in Fig. 4. The furnace

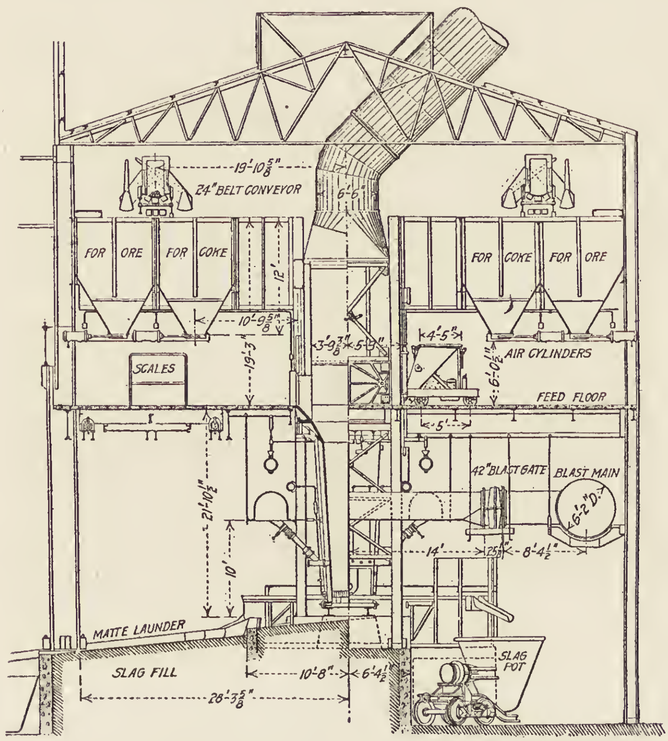

FIG. 4.—Blast-furnace plant, Calumet and Arizona Mining Co.

bottom of ½-in. steel plates is reinforced with 6-in. I-beams at 12½-in. spacing, and the structure is carried on two 12-in. longitudinal beams.

The forehearth, placed between furnaces, is set so high that the slag is easily removed by a slag car of 225 cu. ft. capacity on one side, the matte being tapped to a ladle in the converter aisle on the other. The jackets, extending clear to the distributing plates, are 16½ ft. high by 40 in. wide. The bustle pipe, flat on the bottom, is combined with the truss or girder which takes the thrust of the jackets at their midpoint.

The automatic method of supplying a furnace is most noteworthy. An ore-bin and a coke-bin are provided on each side of the furnaces. These are kept filled by a conveying-belt system from the ore-beds already mentioned, where a reclaiming machine is used. Each furnace has four charge-cars 20 ft. long. When receiving a charge the cars rest on track scales. Each car has four compartments, and the bins overhead have corresponding gates, so that the compartments can be filled as much or as little as required. The car is propelled from the charging position to the furnace by means of an electric motor. Each furnace has 64 tuyères of 4½ in. diam. and uses 68,645 cu. ft. of air per ton of dry charge under a pressure of 27 oz. per sq. in. The average capacity per furnace-day is 996 tons, of which 89.7 per cent. is ore. The coke used is 12.7 per cent.; the flue dust produced is 3.4 per cent. The ores, as charged, on an average contain Cu, 5.29 per cent.; S, 13.1; Fe, 25.9; SiO_2, 22.2; Al_2O_3, 5.3 and CaO, 5.9 per cent., and yield a matte averaging Cu, 28.81 per cent.; Fe, 40 and S, 25.3 per cent. The furnaces have been in operation for 3 years.

The reverberatory department includes four furnaces, 19 by 100 ft. hearth dimensions, with a height of 8 ft. 3 in. at the charging end, and of 4 ft. 3 in. at the front or skimming end. The charge and fettling material are introduced through center-drop and side-drop holes respectively. The furnace capacity, exclusive of converter slag returned to it, is 400 tons. The oil used is 0.752 bbl. per ton of charge. From an average charge, containing Cu, 5.16 per cent.; Fe, 29.3; S, 8.5; SiO_2, 28.3; Al_2O_3, 4.1 and CaO, 3 per cent., is produced a matte averaging Cu, 25.03; Fe, 41.2 and S, 26.1 per cent.

The converter department includes six stands, with two extra shells, of 12-ft. diameter Great Falls type of basic-lined, electrically tilted converters served by two 40-ton Morgan cranes. The matte, tapped from the blast-furnace or reverberatory settlers into 160-cu. ft. cast-steel ladles, is transferred by the cranes to the converters. The molten slag poured into the reverberatory or blast-furnace settlers has an average analysis of 2.79 per cent. Cu. A McGregor skull-breaker handles the skulls, which are resmelted in the blast furnaces.

The molten blister copper, which has a purity of 99.16 per cent., is cast in two 40-mould electrically operated straight-line casting machines, the moulds for which are made of blister copper in this department.

The plant is treating 3000 tons of charge per day and yielding 7,000,000 lb. of copper monthly.

Copper Queen Reduction Works.[1]—This smeltery now has more 12-ft. upright converters. The average of ore treated is as follows: Cu,

[1] *Eng. Min. Jour.*, **102**, 620; Mineral Industry, **24**, 223.

9.13 per cent.; SiO_2, 56; Fe, 8.1; CaO, 1; Al_2O_3, 8.4; S, 6.1 per cent.; Au, 0.075 oz. and Ag. 3.46 oz. per ton. The average charge bedded comprises ores 72.7 per cent.; concentrates 9; limestone 1.5 and secondaries 16.8 per cent. From 10 blast furnaces, on a basis of 4146 tons of charge

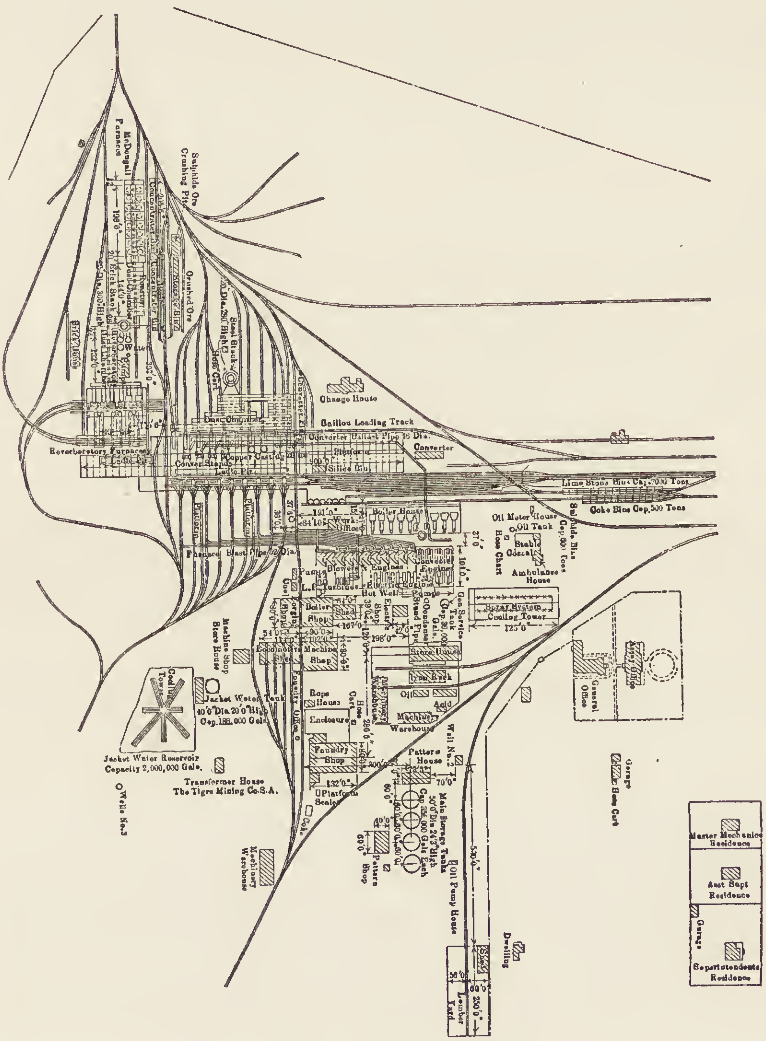

FIG. 5.—Lay-out of Copper Queen plant.

daily, the average per furnace is 374.8 tons, yielding 229.57 tons of copper bullion or 20.84 tons per furnace-day. The movement of charge is 6.1 tons per man per shift. The blast-furnace charge contains 82 per cent. of ore, 16 of secondaries and 2 per cent. slag, to which is added 12 per cent. coke of 79.7 per cent. fixed carbon, 18.2 per cent. ash. The flue dust produced represents but 3.84 per cent. of the charge, which has values of Cu, 6.97 per cent.; S, 12.8 per cent.; Au, 0.026 oz. and Ag, 1.25 oz. per ton. The matte produced contains Cu, 37.6 per cent.; Fe, 31.7 and S, 25.6 per cent.; also Au, 0.165 oz. and Ag, 6.8 oz. per ton. The slag is reported to contain 0.46 per cent. of copper and 0.06 oz. of silver per ton.

The roaster charge consists of concentrates 55 per cent. and crushed ore 45 per cent., while the reverberatories treat a mixture consisting approximately of calcines 80 per cent.; blast-furnace flue dust, 19; converter flue dust, 0.4 per cent.; and ore for fettling, 0.6 per cent. Oil for the reverberatories (0.76 bbl. per ton of charge) is fed in at the temperature of 80° C. under a pressure of 75 lb. per sq. in. The 12-ft. basic-lined converters average 43.23 tons per blow, with a yield of 13.11 tons of blister. The converter blast pressure is 13 lb. per sq. in., using 26,800 cu. ft. of air per ton of blister that has the composition 99.24 per cent. Cu, Au, 0.387 oz. and Ag, 19.47 oz. per ton.

We give in Fig. 5 a general plan of the works,[1] which shows, on the upper left or west side, the reverberatory plant having its supply track running in from the north, while the blast-furnace plant is supplied from the ore beds on the west side, each plant being independent of the other.

The reverberatory plant concentrates are delivered by overhead track to the two "concentrate bins;" the coarse ore is unloaded to the "sulphide ore crushing pit," and is thence conveyed to the "crushed ore storage bin." From these storage bins both ore and concentrates are withdrawn upon belt conveyors running in a trench beneath the bins, and by the rest of the belt-conveying and elevating system, raised and fed by a tripper into any desired roaster feed-hopper. There are 16 MacDougall roasters in two rows and the calcine from them is dropped into special cars, the train also passing beneath the "roaster dust-chamber." The train is withdrawn northward upon the entering track, then by a long track to surmount the three reverberatory furnaces at their fire-ends. A sunken double track brings in the slag train to the slag-taps at the front of the furnaces, this track then joining the blast-furnace slag tracks on the way to the dump.

The blast-furnace plant, a building 150 by 900 ft. long, contains on one of its long sides, 10 blast furnaces, on the other seven 12-ft. upright basic-lined converter stands. In front of the blast furnaces and of the reverberatories are ladle pits, so that matte can be conveniently tapped into 5-ton ladles and thence transferred by traveling cranes to any

[1] *Bull. Amer. Inst. Min. Eng.*, June, 1916, 1085; *Met. Chem. Eng.*, **15**, 169; MINERAL INDUSTRY, **15**, 259; **21**, 256, 24.

desired converter. In this building there is a silica bin, whence crushed material can be withdrawn into silica boats for feeding to converter.

The trackage system from the ore-beds 2000 ft. distant is shown together with the sidings where the coke and limestone are gathered. The train is then raised by a 2 per cent. grade to the feed floor of the blast furnaces. As described in Mineral Industry, **24**, 223, the charge-train is dropped back upon a siding, ready to be taken by locomotive to the ore-beds. A high-line, rising by a 1 per cent. grade, delivers coke to the coke bins.

The "blowers and engines" for the blast furnaces are arranged *en echelon* in order to save space in the power house. Each blower has its own independent blast pipe (10 in all) which pass overhead to the furnaces. (It is now thought that a single main would have been more satisfactory with branches to blower and furnace.) The six blowing engines blow into one main in order to deliver to the converters.

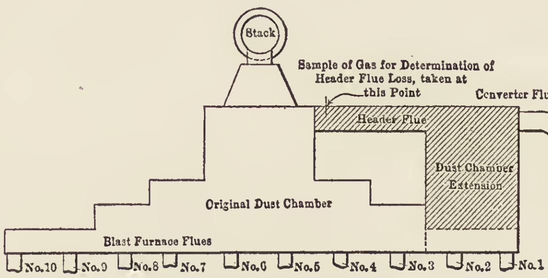

Fig. 6.—Copper Queen dust-chamber.

The roasters and the reverberatory furnaces each have their own dust-chamber delivering to a stack standing close to and between them.

The blast furnace and converter dust-chamber, 336 ft. long, is of the peculiar form shown in Fig. 6 the shaded portion having lately been added. The converter fumes are collected into a single balloon flue of 12 ft. average diameter and this enters at one end of the flue-chamber. Each of the 10 gooseneck furnace flues, 8 ft. in diam., enter the long side of the chamber. The exit at the other side is to the main stack, 20 ft. in diam. by 280 ft. high.

The water supply is pumped from wells to four main storage tanks each 50 ft. in diam., 24½ ft. high, and containing 356,000 gal. From the tanks it is delivered by centrifugal pumps as needed about the works. Jacket-water from the blast furnace goes to a star-shaped cooling tower, the cooled water falling into a jacket-water reservoir of 2,000,000 gal. capacity. Another spray-system cooling tower consists of a reservoir in which are spaced spray nozzles, where the water rises in jets to be air-cooled as it encounters the air.

The locomotive and boiler shops are arranged in relation to the trackage so that the rolling stock can be conveniently moved for repair from all parts of the works.

In 1915 the average tonnage smelted per blast-furnace-day was 363.5, average product per roaster 47.5 tons of calcine; the average daily reverberatory tonnage was 338.7 and blister copper was made at an average rate of 36.2 tons per converter day.

Typical analyses of concentrates, sulphide ore, calcines and flue dust are given in the table herewith.

	Typical Analyses.										
	Oz. per Ton.		Percentages.								
	Au.	Ag.	Cu.	Zn.	Insol.	SiO_2.	Fe.	CaO.	Al_2O_3.	S.	Mn.
Concentrates	0.007	3.50	13.90	....	16.0	11.7	31.3	0.5	3.0	35.0	0.3
Sulphide ore	0.035	0.57	4.16	....	26.8	21.0	30.3	0.8	3.9	31.6	0.3
Calcined concentrates	0.030	4.33	16.18	1.1	.....	12.8	36.3	0.6	3.4	11.8	.....
Calcined sulphide ore	0.070	1.53	6.36	....	.....	19.0	38.0	1.9	3.4	8.0	0.1
Chamber dust	0.030	2.97	11.40	1.2	29.2	21.1	25.7	1.6	5.6	20.7	0.6

	Screen Analyses.											
	Per Cent. Retained on Screen of: Mesh.											Per Cent. through Last Screen.
	2	3	4	8	15	40	80	120	150	180	200	
Concentrates	....	8.0	6.9	19.7	...	25.4	11.4	5.2	3.1	2.2	3.4	10.3 through 200 mesh.
Sulphide ore	19.4	18.2	6.0	15.8	7.5	22.7	4.9	1.6	1.0	....	...	2.9 through 150 mesh.
Dust loss expts. 1–20	....	....	...	....	...	....	....	...	...	....	2.0	98.0 through 200 mesh.
Dust loss expts. 21–45	....	....	...	....	...	....	0.2	0.4	0.7	10.3	...	88.4 through 160 mesh.
Dust loss expts. 46–55	....	....	...	....	...	0.5	1.1	0.4	0.4	0.5	0.6	96.4 through 200 mesh.

NOTE.—Expts. 1–20: Diameter of suction intake 10 in. reduced to 5 in. outside of flue. Expts. 21–55: Diameter of suction intake 6 in. reduced to 5 in. outside of flue.

International Smeltery.[1]—This works at Miami, Ariz., has been briefly described in MINERAL INDUSTRY, **23**, 230; **24**, 222. We give further details as follows:

The reverberatory and converter buildings adjoin; the main stack is set close to the former. The crushing plant and bedding bins are together, and with the dryer plant forms another group of buildings, the dryer building being convenient to the reverberatory furnaces. All ore is handled under cover. The other plant buildings outlie the reduction plant proper.

[1] *Bull. Amer. Inst. Min. Eng.*, Aug., 1916, 1257; Dec., 1916, 2145; *Eng. Min. Jour.*, **101**, 421, 563; 102, 396, 647; *Min. Sci. Press*, **112**, 822.

The smeltery treats flotation concentrates brought by a short railroad line from mills of the Inspiration Copper Co. and the Miami Copper Co. The concentrate is an extremely fine black mud, carrying 16 per cent. moisture and 37 per cent. copper. It comes in special 60-ton cars which have hopper bottoms and a bottom-discharge slit, 2 ft. 3 in. wide, covered by close-fitting creosoted cross-planks. At one end of the car is a cast-steel gate with a screw and hand-wheel attachment to tighten or press together the short planks. When loading, a tapering plug reaching up through the load is stood on the gate. To unload at the unloading pocket, the gate is opened 18 in., the plug is pulled up, and with a bar a man pokes down the concentrates until there is room for him to get down and complete the successive removal of the planks for the unloading. The car is then swept clean, the planks replaced, the gates closed, and all joints tightened ready for loading.

When unloading the material falls upon a conveying belt which takes it to the sampling mill. The falling stream from the head of the conveyor from the unloading pocket falls upon a "shuttle" conveyor and thence by any one of the three conveyors to the bedding bins.

Beneath the bedding bins are belt conveyors. Like the concentrate cars these bins have bottom slots covered by short cross-planks to be successively removed when emptying the bins.

The moist concentrates now arrive at the drier plant. Here are five Wedge roasting furnaces, used for drying only. These are 22 ft. 7 in. diam. of shell, and have six hearths. Cooling air, after passing through the furnace arms, is conducted up the central shaft to the top, thence down to the oil-burning fire-boxes at the two lower hearths. This gives preheated air for combustion of the oil. The linings are 12 in. thick, and the outer 4 in. of lining between the hearths is of "Nonpareil" insulating brick, claimed to have an insulation equivalent to 40 in. of ordinary brick. The calcine hoppers also have a 2½-in. lining of Nonpareil brick and a 1-in. layer of reinforced concrete, the latter to take the wear which the Nonpareil will not stand. No roasting is permitted, as there is a shortage of sulphur. To ensure the required matte-fall when the ore is smelted, sulphide ores from Bisbee are added. The oil burners used for the drying consume 5.15 gal. of oil per ton of charge. The extremely fine concentrate makes much dust, which is effectively caught by the Cottrell apparatus installed in the upper part of the dryer building, so that the final dust loss is but 0.7 per cent.[1]

Each of the 12 units of the Cottrell equipment comprises 20 vertical tubes 13 in. in diam. by 15 ft. high, bellied outward and flanged at each end

[1] The charge for the drying furnace consists of concentrates 84.9 per cent., crushed ore 0.2, converter secondaries 7.1, pyrite 2.1; limestone 5.7 per cent. Of this 207 tons is treated per furnace-day. The dried charge carries 28.43 per cent. copper.

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and then riveted to the header sheets. This expansion at the ends reduces the electric discharge caused by sharp corners. Axially in the tubes are No. 10 steel wires suspended from a glass-insulated steel frame that receives a 50,000- to 60,000-volt electric current. Each wire is kept tight by a 5-lb. cast-iron weight. Any unit may be by-passed for cleaning and removal of the dust. The dust is jarred off by hand-operated multiple hammers giving a longitudinal blow to the pipe through a steel lug welded to it.

The calcines leave the dryer at a temperature of 165°, while the gases in the Cottrell apparatus are at 80°. These gases rise through the tubes at a velocity of 3 ft. per sec. and contain CO_2 4.4 per cent. and CO 14.4 per cent.

The calcines are taken to the three reverberatory furnaces in 18-ton closed steel cars. The car has four sliding sleeves on top, spaced to match and to make a close joint with the calcine hoppers at the dryer plant. An air vent, covered by a screen, permits the escape of the air displaced when loading. The two discharges at the bottom of the car are similarly sealed when the car arrives at the reverberatories.

The unaccounted loss of the plant is heavy, being 0.7 per cent., equivalent to 2 tons of copper per day. Much of this loss appears to come from two sources, viz., from dust created in charging and discharging the calcine cars, and from dust blown into the air when turning the converters up and down. Exceptional precautions have been taken to unload under cover, to protect all belt conveyors and spreading beds from the wind. Walter Douglas[1] states that in an early experience the losses were supposed to be confined to slag loss and volatilization of the copper through the stack. S. J. Jennings also draws attention to the material loss in dumping, especially where, as in the Southwest, the air is so dry, and where occasional high winds occur.

A. G. McGregor states that, realizing the wind losses that might occur, they have, at the International plant at Miami, Ariz., housed in all the beds. Walter Douglas states that this is justified by the 25 to 35 per cent. product treated, and considers that for a plant treating a low-grade ore such precautions are hardly necessary. As to the stack losses the samples obtained by filtering the smoke indicate a most complex fume containing the rarer elements, arsenic, bismuth, platinum, copper, silver, zinc and some gold.

As shown in the typical cross-section, Fig. 7, each reverberatory, 120 by 21 ft. hearth dimensions, is oil-fired, and has Stirling waste-heat boilers. In building the furnaces molten slag from a small blast furnace was laundered to the foundations. Also heavy concrete beams and

[1] *Bull. Amer. Inst. Min. Eng.*, Dec., 1916, 2148.

struts were provided between the furnaces to take the thrust of the furnace buckstaves. Later, molten slag from the reverberatories themselves was used to fill the spaces between and among these beams and trusses. The slag bottom was covered, first with a 4-in. layer of fire-clay, then by a 37-in. layer of silica rock of 94 per cent. silica, crushed to ¼-in. size. The bottoms did not come up in starting. Two charge tracks cross the furnaces near the firing end, and the calcine cars discharge into bins beneath the tracks. In order to distribute the charge along the sides of the furnace, drag-chain conveyors are installed in a lined trough, one at each side, receiving the charge from the charge-hoppers. Under the lined troughs at 30-in. intervals are 6-in. cast-iron feed pipes with gates to regulate the supply as needed along the sides within the furnace. The bridge walls and side walls are supplied by drawing directly from the charge bins through spouts. The reverberatory gases, after passing the

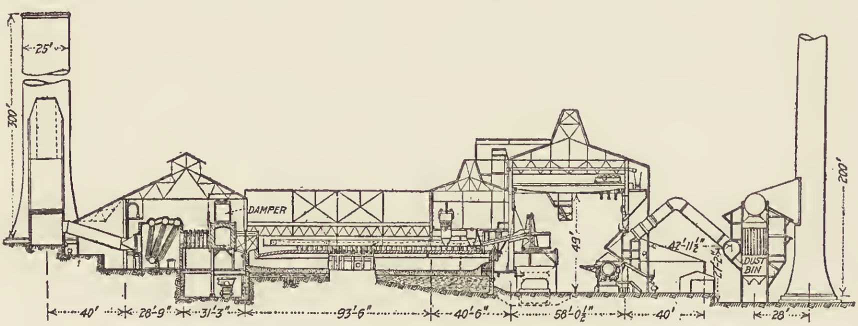


Fig. 7.—Reverberatory building, International smeltery.

waste-heat boilers, go by a main reverberatory flue to a separate stack 300 ft. high, 25 ft. in diam. It is computed that the loss here is 0.185 per cent. of the total copper charged.

To the charge already specified for the drying furnaces is added up to 13 per cent. of converter slag. The solid charge is 484 tons daily, and per ton of charge, the oil used is 0.79 bbl., this amount also producing 1324 lb. of steam at 187 lb. per sq. in. The furnace temperatures are, at the bridge 1540° C., at the throat 1220°, after passing the boilers 300° C. At the throat the gases carry CO_2, 14.6 per cent. and O, 2.6 per cent. The draft is 0.25 in. of water. The temperature of the oil at the burners is 99° C., and the pressure 80 lb., while the pressure of air used in atomizing is but 8 lb. per sq. in.

There are five upright basic-lined Great Falls type converters tilted by 50-hp. alternating-current motors. Referring to Fig. 7, converter slag is received into the crane ladles, which pour it by launder into the reverberatory furnaces. Silica bins are set over the converters. These are supplied by a 20-in. conveying belt and tripper to any desired bin. Below each silica bin is a weighing hopper of 38 cu. ft. capacity to receive silica additions to be spouted to the converter as required through a 10-in. pipe that can be swung aside when not in use. To serve the converters there are two 40-ton three-hoist electric cranes with magnet-switch controllers. For casting the copper there are provided two straight-line casting machines where the copper is cast into slabs of 274 lb. each. Each machine has a capacity of 259 tons daily. For the ladle skulls, etc., there is a McGregor skull-breaker conveniently placed in the crane aisle to receive them. The machine has a grate area of 12 by 24 ft., thus providing sufficient storage room before breaking. Beneath the grating there is room for an ore car to take the crushed material. The blast pressure at the converters is 12 lb. per sq. in., and per ton of blister copper, 142,000 cu. ft. of free air is used. The average time of a blow for each addition of matte is 3 hr. 10 min., in which period 26.9 tons is treated, producing 13.7 tons of copper, the grade of the matte being 51.05 per cent. For each ton of copper there is used 0.3 tons of siliceous ore. The daily output per converter is 95 tons.

The converter gases are taken by goosenecks, 6 ft. in diam., to a balloon-shaped header-flue which parallels the Cottrell converter installation in a separate structure, 192 ft. long, the Cottrell treater having 768 tubes similar to those at the dryer plant. Short pipes from the header flue connect to the individual units of the installation and these in turn to a common header leading to the main stack. It is estimated that the loss at the Cottrell plant amounts to but 50 lb. of copper daily, and mostly occurring when a converter is turned down to pour.

The main stack is 30 ft. in. diam. inside by 400 ft. high. It has a 4-in. brick lining back-filled with clay. At the base are openings for the roaster, the blast furnace and the reverberatory furnace flues respectively, also a clean-out door, 4 by 6 ft.

The electrical apparatus of the two Cottrell plants is placed on top of the dryer building. It comprises 10 General Electric transformers of 50,000, 75,000 or 100,000 volts, the motor-generator sets with rectifiers on the same shaft, two motor-generator exciters, and the necessary switchboards.

The cost of the two plants, electrical apparatus, etc., as installed and excluding the royalty and the foundations was as follows:

Steel structure	$55,017.78
Ten motor-generator sets with rectifiers	7,126.48
Switchboards	3,124.68
General Electric transformers	10,667.17
High-voltage wiring	8,546.55
Low-voltage wiring	953.47
Cottrell tubes and shaking equipment	28,456.09
	$113,892.22

The dryer plant has 240 tubes, the converter plant 768, making a total of 1008 or $113 per tube. At the dryer plant the duty is 225 cu. ft. per min.; at the converter plant 350 cu. ft. per min. The velocity of the gases in the first instance is 3 ft. per sec.; in the second, 4.7 ft. per sec. and at a higher temperature, viz., 150° C.

The power consumption was 27,000 kw. monthly. Direct operating expenses per month are for operating, labor, power supplies and expense, $1188.79.

A modern power-plant, owned jointly by the Inspiration Consolidated Copper Co. and the International Smelting Co., consists of three 6000-kw. turbo-generators and three cross-compound 5000-cu. ft. blowing-engines; the steam for the plant is furnished by the reverberatory waste-heat boilers and by oil-fired boilers near the power-house.

Following are the analyses of the ores and products of the smeltery:

	SiO_2	Al_2O_3	Fe	CaO	S	Cu
Concentrate	16.8	6.5	13.4	0.4	20.2	35.2
Siliceous ore	65.7	13.8	1.4	0.5	....	4.5
Conv. secondaries	15.7	3.5	41.1	1.0	6.1	16.6
Converter slag	19.2	4.1	51.0	0.5	1.1	3.5
Reverberatory dust	19.8	9.5	4.2	2.0	9.9	18.3
Converter dust	5.0	2.0	5.2	0.6	15.0	34.0
Pyrite	4.6	1.1	41.3	....	45.0	2.3
Limestone	4.4	....	....	48.8	....	....
Dryer dust	27.0	12.5	5.6	1.4	8.4	25.6
Reverberatory slag	40.2	12.7	27.0	4.3	....	0.8
Reverberatory matte	....	....	21.6	....	24.5	51.7

The recovery of copper during the first 4 months of 1916 was 97.3 per cent. In March, 1916, the production of blister copper was 8111 tons.

The solid charge handled by the furnaces per day is 1125 tons, of which 877 tons is concentrates. The copper content of the new material is 281.5 tons with 9 oz. gold and 780 oz. silver, producing 275 tons of copper, 8 oz. gold and 700 oz. silver.

United Verde Smeltery.[1]—The Clarkdale plant of the company is described fully in Mineral Industry, **24**, 222.

The blast furnaces, 26 ft. 8 in. long by 48 in. wide, have an interesting feature in the Giroux hot-blast tops (see **22**, 235; also description of the Katanga furnaces, on a preceding page). The three blast furnaces put through 2200 tons daily, yielding 5,000,000 lb. of copper per month with 4.5 per cent. copper on the charge. Running the same pyritically with 22 per cent. sulphur on the charge, and using 5.8 per cent. of coke, there is yielded a matte of 23 per cent. copper, being a concentration of 5 to 1.

The 19- by 100-ft. oil-fired reverberatory smelts 350 to 400 tons daily of solid charge with a consumption of 0.75 bbl. per ton of charge or 0.5 bbl. if we allow for steam credit at the waste-heat boilers. For fettling,

[1] *Met. Chem. Eng.*, **15**, 170, 251.

ore running 65 to 80 per cent. SiO_2 is used, as arrangements are poor for putting in any considerable quantity along the side walls. The charge consists of calcined ore and flue dust, and no concentrates are added.

At the converters 2 tons of ore of 60 to 75 per cent. SiO_2 are used to each ton of copper produced.

The capacity of the plant is about 3000 tons of charge daily and production amounts monthly to 5,000,000 lb. of copper in which is contained a small amount of gold and silver.

The Hayden Smeltery.[1]—This plant of the American Smelting and Refining Co. has a monthly capacity of 25,000 tons, yielding 8,000,000 lb. of copper containing some gold and silver.

The Tennessee Copper Co.[2]—This company at Copper Hill, with mines at Ducktown, shows profits of 24.85 per cent. on its capital stock, profits derived as much from the production of acid as from copper. For the year, 475,301 tons of ore yielded 12,750,418 lb. of copper (26.83 lb. per ton) 60,953 oz. of silver and 276 oz. of gold; also there was produced from the ore 210,666 tons of sulphuric acid of 60° Bé.

The costs per pound of copper were:

Total costs of mining and smelting	$0.08768
Freight, insurance, refining, selling expense less gold and silver credited	0.01206
Administration and legal expenses including taxes	0.00551
	$0.10525

The material smelted includes:

	Tons.
Tennessee copper ore	448,921
Converter slag (includes 13,631 tons of ore)	21,269
Blast-furnace slag	11,712
Sinter (includes 9873 tons of ore)	14,001
Quartz	83,671
Limestone	12,180
Matte (includes 2876 tons ore)	43,877

One notes the large amount of barren quartz smelted to insure a matte of about 15.5 per cent. and a matte-fall of 9 per cent.

Cerro de Pasco Smeltery.[3]—This works is at La Fundicion, Cerro de Pasco district, Peru. Crude ore is screened to ¾-in. mesh, the coarse directly smelted, the fines sintered on six Dwight-Lloyd machines with a total capacity of 250 tons daily. There are six reverberatory and four blast furnaces, each of 300 tons daily capacity. The slag is granulated. Coal and coke are produced from the two mines of the company 26 miles distant. The coal is, roughly speaking, one-third fixed carbon, one-third volatile matter, one-third ash, and is high in sulphur. Washing reduces the ash by one-half, and raises the fuel value to 6600 Cal. Limestone is furnished for flux from a limestone quarry between the coal mines and the smeltery.

[1] *Met. Chem. Eng.*, **15**, 170.
[2] Annual Report of Tennessee Copper Co.; *Eng. Min. Jour.*, **101**, 805.
[3] *Eng. Min. Jour.*, **101**, 1018.

Metallurgical Losses

Dust Losses at the Copper Queen Reduction Works.[1]—J. Moore Samuel presents the result of his investigations of these losses.

In order to obtain a representative sample, having the same dust content as the escaping flue gas, it was necessary (1) that the gas sample should be drawn off at the same rate of flow as the main current, (2) that the quantity taken should be large enough for accurate chemical determination and (3) that the ratio of the quantity taken to the total flow should not be too small. To fulfill these requirements the velocity of flow in the main current was determined by a Pitot tube, and the sample was withdrawn at the same velocity through a filter bag of asbestos fabric.

Experiments were made on the roaster flue leading to the stack. A cross-section of the flue shows the variation of dust content at 50 equally spaced points. From it we note (1) that the percentage of contained dust increases with the velocity, (2) that in the middle part of the cross-sectional area of the flue (36 per cent. of the total area) some 59 per cent. of the total gas volume passes, and this volume carries 89 per cent. of the dust. Along the walls the gas carries roughly 0.20 per cent. of dust at a velocity of 5 to 10 ft. per sec.; in the free central area, the gas, at a velocity of 20 to 25 ft. per sec. carried 0.50 to 0.55 per cent. of dust. When 15 roasters were in operation, putting through collectively 750 to 800 tons daily, the dust loss would average 31 tons in 24 hr., being 4 per cent. of the charge.

The reverberatory dust losses are negligible; the dust settles mostly at the waste-heat boilers, and but little in the chamber. Accordingly it is planned to build a flue to connect the dust-chambers, and another to carry the waste-heat gases directly to the stack.

The dust losses at the main or blast-furnace stack have been cut down, first by increasing the size and arrangement of the main flue-chamber, and second by sending the fine ore and the flue dust to the reverberatories. Thus, in 1909, before the main dust-chamber was altered, with a daily output of 3000 tons for nine furnaces and with six converters in operation, the daily loss was 164,000 lb. of dust, being 2.73 per cent. The temperature of the gas was 170° C. and it carried 0.162 per cent. of dust. In June, 1911, when the dust-chamber had been altered, then under the same operating conditions, the daily loss fell to 61,000 lb., being 1.03 per cent. of the charge and the gases carried but 0.076 per cent. of dust. Furthermore, when no more fine concentrates or flue dust was put upon the blast-furnace charge, the flue-dust loss was but 41,000 lb., being 0.67 per cent. of the ore charged and equivalent to 0.0615 per cent. of dust in the gases.

[1] *Bull. Amer. Inst. Min. Eng.*, June, 1916, 1079; Dec., 1916, 2148; Mineral Industry, **21**, 257.

Metal Losses in Copper Refining.[1]—Lawrence Addicks classifies these losses as follows:

A, Weighing; *B*, Sampling; *C*, Assaying; *D*, Slags; *E*, Stack Losses; *F*, Process Losses; *G*, Handling Losses. Taking these in order we have:

A. Weighing	(*a*) Incoming blister copper.
	(*b*) Outgoing copper.
	(*c*) Outgoing silver and gold.
B. Sampling	(*a*) Moisture.
	(*b*) Errors in sampling method.
	(*c*) Salting.
C. Assaying	(*a*) Assay methods.
	(*b*) Splitting limits.
	(*c*) Assay errors.
D. Slags	(*a*) Cupola slag.
E. Stack Losses	(*a*) Anode-furnace stacks.
	(*b*) Refining-furnace stack.
	(*c*) Silver-refinery stack.
	(*d*) Cupola stack.
F. Process Losses	(*a*) Silver and gold in outgoing copper.
	(*b*) Silver in outgoing gold.
	(*c*) Gold in outgoing silver.
	(*d*) Minor losses.
	(*e*) Process margins.
G. Handling Losses	(*a*) Wind losses.
	(*b*) Shaft losses.
	(*c*) Solution losses.
	(*d*) Soil losses.
	(*e*) Slime losses.

Copper and Its Alloys

Melting and Refining Copper.[2]—We have noted (Mineral Industry, **22**, 241) Addicks' and Brower's improvement in the adaptation of a basic lining in a copper-refining reverberatory. The walls are of chrome brick, the hearth of magnesite brick. A basic furnace permits of the refining of foul material without the necessity of adding an admixture of a large quantity of better-grade blister or cathode copper. Moreover, when melting cathodes, there is practically no formation of slag, whereas with an acid-lined furnace as much as 3 per cent. is formed. To promote this condition the molten charge should be covered with charcoal, and fuel ash from the fire-box should not get to the bath.

[1] *Met. Chem. Eng.*, **15**, 11.
[2] U. S. Patent 1,148,814, Aug. 3, 1915.

Boron-copper for Deoxidizing.[1]—The American Boron Products Co., Reading, Pa., is making this alloy of which it is stated that an addition of 1 to 5 per cent. will remove the impurities from a bath of molten metal. In varying proportions it may be used in the production of copper castings, aluminium bronze and to prevent the loss of zinc when making or melting brass. The tensile strength of nickel steel is said to be increased by substituting boron-copper for one-half the nickel.

Poling Molten Copper.[2]—E. C. King holds that the reduction poling of the copper bath can be accomplished by introducing a hydrocarbon oil, air-free, through a pipe with its nozzle beneath the surface of the molten metal.

Moulding Blister Copper.[3]—The molten copper from the converters is received into the cast-steel ladles lined with the fines from the fluxing ores used in the converters. The blister copper moulds are made from blister copper, and to protect the bottom of a mould, a 1¼-in. splash-plate is used, this being large enough to cover half the bottom area of the mould. To cast a ladle full of blister copper takes 35 min. The bars weigh 240 lb. each and are 99.6 per cent. pure. Naturally, they are rough, due to escaping gas taken up when blowing to attain this grade.

Changes in the Structure of Industrial Brasses.[4]—D. Meneghini has investigated the cause of the rapid corrosion of brass-tipped burners. He considers this due to the flame backing into the burner, and so bringing its temperature to as high as 400° C. A local heat like this tempers part of the brass, producing a eutectic γ which gives fragility to the brass. The sound part had only the solid solution α and the former β and γ were observable in the fragile portions.

Corrosion of Cannon-bronze.[5]—Cecil H. Desch and Henry Hyman have examined two branches respectively of 87.8 and 83.5 per cent. Cu with 9.5 and 14.0 Sn. Each alloy has also an average of 2.4 per cent. Zn. The alloys were heat-treated, both by casting in a hot mould, then cooled in the air; also heated to 800° C. and slowly cooled. The first treatment made the alloy more resistant to corrosion. Tin exercises its protective influence, forming a whitish coat of adherent basic salts.

Resistance of Copper Alloy.[6]—L. P. Webbert finds that test pieces of 0.8 in. give more uniform and reliable results than those of 0.55-in. diam. Three alloys of 87 to 88 per cent. Cu, the remainder chiefly tin and zinc with lead and iron as impurities, gave an average ultimate strength of about 35,000 lb. per sq. in. with elongations of 25 to 30 per

[1] *Min. Eng. World*, **44**, 569.
[2] *Min. Eng. World*, **44**, 1004.
[3] *Min. Sci. Press*, **133**, 570.
[4] Inst. of Metals, 1915.
[5] Inst. of Metals, 1915.
[6] Am. Soc. for Testing Materials, 1914.

cent. in 2 in. We can compare this with an alloy containing 84.5 per cent. Cu, 15.5 Zn, 0.8 Sn and nearly free from other metals, which gave an ultimate strength of 68,000 lb., with a similar elongation to those above. Another alloy of 57.7 per cent. Cu, 39.8 Zn, 0.8 Sn with 0.7 Fe, 0.16 Mn and 0.6 Al was even stronger (72,000 lb. per sq. in.) with the usual elongation.

Hardness of Brasses.[1]—D. Meneghini finds that the alloys of over 84 per cent. zinc are alone homogeneous, the others are often porous, as well as very hard and brittle. He used a testing machine described by Le Gris, similar in principle to that of Brinell, which makes a depression in the sample. The softest are the brasses of 57 to 66 per cent. zinc.

Brittleness of Annealed Copper.[2]—W. E. Ruder of the General Electric Co. shows that with ordinary commercial copper brittleness begins to appear at 400° C. in dry hydrogen, at 700° C. in steam. Copper, previously deoxidized by the addition of boron, is unaffected at all temperatures in a reducing atmosphere. The brittleness is therefore due to the reduction of the cuprous oxide around the primary copper grains, leaving a spongy mass of little mechanical strength.

Strength and Ductility of Electrolytic and Arsenical Copper.[3]—C. H. Mathewson and E. M. Thalheimer have compared arsenic-free electrolytic copper with two varieties of Lake copper, one being Mohawk copper carrying 0.096 per cent. arsenic, the other Copper Range copper having 0.296 per cent. They have tested cold-worked test strips made from them for tensile strength, elongation, and reduction of area, the strips being ¾ in. wide, and varying in thickness from 0. 1315 to 0.0395 in. The tests failed to develop any striking differences of rolling temper between the different brands of copper used. The Copper Range product decreases in ductility more rapidly than the electrolytic copper during the earlier stages of rolling, but in the later stages about equally. Strength is equal at first but later Copper Range increases faster than electrolytic. As to reduction of area, all three kinds show the same values of reduction of area after such reduction has passed 35 per cent. Copper Range takes a harder temper on rolling, but does not ultimately become less ductile than electrolytic, and it would seem either would stand the same amount by rolling. In rolling previously annealed metal from No. 8 to No. 12 B. & S. gauge (a reduction of 40 per cent.), Copper Range would have a tensile strength of 2000 lb. per sq. in. over electrolytic metal similarly treated, while elongation would be about the same in either case.

With respect to strips annealed 40 min. at different temperatures after

[1] Inst. of Metals, 1915; Rev. de Metallurgie, Jan.–Feb., 1916.
[2] *Trans. Amer. Electrochem. Soc.*, Apr., 1916; *Met. Chem. Eng.*, **14**, 475.
[3] *Bull. Amer. Inst. Min. Eng.*, July, 1916, 1185.

a reduction of 50 per cent. in rolling, these strips being 0.75 in. wide by 0.06 in. thick, it was found that a dull red heat produces equally satisfactory results for both electrolytic and Copper Range metal, and that the latter showed the highest values of elongation and reduction of area over the former. If the metal is allowed to come to a bright red in annealing, a Copper Range load may be expected to emerge with about the same ductility as an electrolytic load annealed to low redness.

In tests made after annealing under reducing condition, as in a gas flame, brittleness and lack of elongation was obtained with a reducing annealing at 800 to 1000° C.

An extended discussion is presented respecting the microstructure of the specimens to which the reader is referred.

Hydrometallurgy of Copper in 1916

Leaching Slime Tailings.[1]—Slimed material from Burro Mountain ore was treated as follows: The thin tailing pulp was thickened to the consistency of 1 to 1 in a Dorr thickener. The thickened pulp was run into shallow basins, and dried to leave 10 per cent. moisture. The lumpy residue was crushed to break up the lumps, then sent to a standard six-hearth 18-ft. MacDougall furnace, where 100 tons of it were roasted, using 3½ gal. fuel-oil per ton, and at a temperature of 480° to 595° C. The material averaged 0.84 per cent. copper before roasting, and the calcines averaged 0.74 per cent. copper, the loss being no doubt due to hydrous copper sulphate carried away in the flue dust. The hot calcine was discharged into a sloping trough containing a 3 to 4 per cent. solution of sulphuric acid where 90 per cent. of the copper was brought into solution. The difficult operation of removing the dissolved copper from the slime was solved by adopting the plan of continuous counter-current decantation, using Dorr thickeners. The liquors, during an experimental run, accumulated sulphate corresponding to Cu, 10 lb.; Fe, 4.3 lb., Al_2O_3, 16.2 lb. per ton, the consumption of acid being 49 lb. per ton. The experiments indicated that an extraction of 70 per cent. could be maintained in practice.

Leaching "Porphyry Copper" Tailings.[2]—R. M. Atwater, Jr., proposes to thus treat tailing dumps containing for example 5 to 15 lb. copper per ton, of which 4 to 10 lb. may be in oxidized form. The tailing pile is levelled and laid out in blocks or squares, and a light railroad track commands it. Cars deliver sulphuric acid solution by spray attachments to the squares, using about 1 lb. of H_2SO_4 per pound of copper present. The copper sulphate formed as the heap dries is brought by capillary

[1] *Min. Eng. World*, **44**, 121.
[2] *Met. Chem. Eng.*, **14**, 452; U. S. Patent 1,175,381.

attraction to the surface, and the thin surface layer is scraped off mechanically. The copper-bearing material, thus concentrated, is then treated to extract its soluble copper.

Electrolytic Precipitation.[1]—R. R. Goodrich has patented a system of step precipitation from a copper-containing solution obtained from the treatment of copper ores.

Leaching Tailings at the Copper Queen Mine, Douglas, Ariz.—Certain waste dumps of oxidized material, carrying 1 per cent. copper, have been treated of late by making from them flat-topped heaps arranged for leaching. Acidulated mine waters, which have been acting upon the waste material of abandoned stopes, this carrying so much pyrite as to heat up the liquor, are brought on to the heaps. In addition the tailings-solution from the leaching plant of the company (see MINERAL INDUSTRY, **24**, 247), which contains ferric oxide, is also brought as a wash upon the leach-heaps. In this way some 50 per cent. of the copper is recovered in 2 weeks, while 85 per cent. is yielded as the result of 6 to 8 weeks' percolation. The cost of making up the heaps is 50 cts. per ton, and the cost for recovery of the copper 3¼ cts. per lb.

The Nevada Douglas Leaching Plant.[2]—A. J. Orem, superintendent at this plant, gives his reasons for crushing to 60-mesh instead of to 20-mesh, as originally planned. The small-scale work indicated that serious dust losses would result from using the finer mesh. On the other hand, they have found it possible in large-scale work to get a more concentrated SO_2 gas, and moreover they now carry the combustion gases through the leaching tanks, where the dust can be recovered. Finer grinding results in ultimate saving. Thus, by acting upon 60-mesh stuff with stronger gases, extraction is effected in 20 min., where with the coarser material, it would take 2 hr., and the capacity of the roaster has been doubled. The finer material is quickly penetrated by the heat, and brought into closer contact with the air. In large-scale work it has cost about 80 cts. per ton to roast ore crushed to 20-mesh size, and with a daily output of 40 tons, while with 60-mesh material, the furnace has put through 80 tons daily without additional cost. Each ton of sulphide ore thus roasted will furnish sufficient sulphur gases to leach 1 ton of roasted sulphide ore and 5 tons of oxidized ore in addition. With the improvements now put in, the plant has a daily capacity of 250 tons of ore.

Chloridizing and Leaching by the Virginia Smelting Co.[3]—This new plant at West Norfolk, Va., is designed to treat 150 tons daily of copper-bearing pyrite from the sulphuric acid plants. About 60 tons, high in copper, will be chloridized and leached, while 90 tons, of low tenor, will

[1] U. S. Patent 1,171,782
[2] *Min. Eng. World*, **45**, 609.
[3] *Eng. Min. Jour.*, **101**, 803.

be leached raw with salt water and dilute sulphuric acid. The copper of the solutions will be precipitated on scrap iron. The leached residues are sintered on Dwight-Lloyd machines for subsequent smelting in iron blast furnaces.

The material comes to the works by barge, is discharged into standard-gage railroad cars, and switched by a long trestle 22 ft. high to the cinder-storage bins. From there the cinder is fed by a system of belt conveyors to the crushing plant, and thence to the mixing-bins. These bins also contain salt and pyrite. From them belt feeders discharge on a collecting belt, which carries the mixture up an incline to the mixed ore bins. These operations are performed on the day shift. From the mixed ore bins the material is drawn at frequent intervals by a series of feeders, conveyors and a vertical elevator to the top of a Ramen-Beskow chloridizing furnace. The furnace is of the square-shelf type. Producer gas is burned on the upper hearth of the furnace, the products of combustion escaping through a steel stack. The remaining four hearths are down-drafted, the gases from them being forced by a fan through a chlorine tower where the chlorine of the charge mixture is absorbed and furnishes a dilute acid liquor for leaching the cinders. The chloridized material is received into concrete storage bins, whence it is drawn once a shift into a steel skip and to any desired hopper over any one of the 12 leaching tanks. The material, thus quickly filled into the leaching tank, rapidly heats the first leaching solution of either dilute wash or of fresh salt water which removes the water-soluble copper. Next comes a dilute acid solution from the chlorine tower followed by a salt-water wash, when the tailings are ready for discharging. The material is loaded from the tanks by means of a grab-bucket and locomotive crane into 50-ton railroad cars. The cars go to the bins for feeding the Dwight-Lloyd machines, where the material is sintered to fit it for blast-furnace use.

The low-grade sinter, leached raw, is delivered by locomotive crane directly to the leaching tanks, and is here treated like the chloridized material and then goes to the sintering machines.

The pregnant solution from the leading tanks is precipitated by scrap iron, the cement copper being washed over a fine screen and allowed to drain on filter bottoms; it is then ready for shipment.

A plant of this type is more expensive than a smelting-converting plant of the same capacity.

Leaching Plant of the Calumet and Arizona Copper Co.[1]—J. C. Greenway, the general manager, describes work done in 1914–1915 and the plant now to be erected for the treatment of the developed 20 million tons of 1¼ per cent. copper ore:

[1] *Min. Sci. Press*, **112**, 522.

The experimental work, covering the treatment of 291 charges, aggregating 12,222 tons, showed that the tailings persistently retained an average of 0.28 per cent. of copper from an ore varying from 1.25 to 1.33 per cent. copper, so that the extraction increased with the grade of the ore. The pounds of copper per kw.-hr. has been increased, being but 0.72 lb. at first, until at the end of the experiments it has increased to 1.125 lb. per kw.-hr.

The permanent plant, to cost $4,200,000, is built for the production of 36,000,000 lb. copper from an estimated amount of 1,700,000 tons of ore annually. Three 100-ton steam shovels will load the ore into 20-ton side-dump cars, which haul it 1 mile to the coarse crushing plant.

The ore at this plant is reduced to 3½ in. in diam. by a No. 24 gyratory crusher and by four No. 8 gyratory crushers in succession, and is delivered to bins of 10,000 tons capacity. From the bins it is withdrawn to the fine-crushing plant where it is reduced to ½-in. size by means of 12 Symons disk crushers. An ore-sampling plant will be erected between the fine-crushing plant and the leaching plant.

At the leaching plant are 11 lead-lined leaching vats, each 88 ft. square by 15 ft. deep, of 5000 tons capacity; also one sludge tank of the same dimensions. These are set in two rows with a central structure between, which supports the conveyors carrying the ore from the fine-crushing department to the vats, as also the circulating pumps and the necessary solution launders. Each vat will have its pumping equipment for circulating and advancing its solution at the rate of about 8000 gal. per min. There are five wash-water and acid-solution storage tanks of 430,000-gal. capacity each to receive and distribute the solutions.

The fine-crushed ore is evenly distributed on the vats, there leached, using the barren solution from the electrolytic vats, and washed to remove all soluble copper. The resultant tailings will be loaded on the afternoon shift by Hulett excavators (such as are used for unloading cargo-boats in the iron-ore trade) into 20-ton side-dump cars to go to the waste dump, the cars and locomotives having been used on the morning shift for loading the mine ore to the plant from the mine.

The neutral copper-bearing solution from the electrolytic cells, collected in the neutral-solution storage tank, is sent to four sulphur dioxide absorption towers, each 20 ft. in diam. by 40 ft. high, where the gas reduces a sufficient portion of the ferric iron to ferrous form to suit the requirements of electrolysis.

From the absorption towers the solution is pumped to the supply tanks at the electrolytic building, where it is circulated through the cells, and the resultant acid solution returned to the acid solution tank at the leaching plant. The tank house will consist of two main aisles, each 80 ft. wide by 270 ft. long, and will contain 152 lead-lined electrolytic tanks, each 30 ft. long, 4 ft. wide and 5 ft. deep, with the necessary cranes, pump circulating equipment and sumps.

The power-plant building, 126 ft. wide by 200 ft. long, is divided by a mid-partition into two. One, the boiler room, will contain five 822.6-hp. Stirling boilers, set for oil firing and with economizers and feed-water equipment. The other half of the building has the two 7500-kw. steam turbines driving the motor generators that supply direct current for the electrolytic plant.

For water supply there is one 300,000-gal. tank, for oil two tanks of 15,000-bbl. capacity, and for a suitable supply of acid four tanks each of 150,000 gal., all so arranged that oil and acid flow by gravity from the tank cars to the tanks.

Leaching Shannon Copper Co. Tailings.[1]—Experiments have been undertaken in a 25-ton plant, and a new plant with a first unit of 150 tons daily is being built. The tailings passing a 1-mm. screen are highly basic, so that sulphuric acid can not be used. They contain 1 per cent. copper, of which 55 per cent. is oxidized, occurring as malachite and azurite with a little chalcocite. The process consists in giving the tailings a sulphatizing roast in a multiple-deck oil-fired furnace, the calcine being leached by decantation with the water only, and subsequent precipitation effected by means of scrap iron.

In roasting, the aim is to maintain the temperature, as controlled by a pyrometer, at 445° to 460° C.; but, if this increases to 500° C., there occurs a re-formation of insoluble basic copper sulphate and oxide. To assure the lower temperatures, the sulphur in the tailings, already 0.5 per cent., is increased to 1 per cent. by the addition of pyrite. The roaster gases contain less than 0.1 per cent. of sulphur dioxide. The consumption in a 25-ton roaster is 5 gal. of oil per ton, and probably as little as 3 to 3½ gal. in a large roaster.

Leaching is effected in a series of three Dorr thickeners by counter-current decantation. From the roaster the calcine is discharged into a circular mixing tank where it receives return liquor from one of the thickeners. From the mixing tank the pulp and solution pass to three Dorr classifiers in order to separate the sand from the slime. The sand is rejected while the slime goes to the three thickeners in series, the first one delivering its clear overflow to the precipitation boxes or tanks. As the pulp progresses through the thickeners it is washed by water and waste liquor from the precipitation boxes. Tests in the 25-ton plant indicate an extraction of from 65 to 77 per cent. Electrolytic precipitation has also been considered.

[1] *Bull. Amer. Inst. Min. Eng.*, Dec., 1916, 2160.

Wet Treatment of Tyrone Concentrates.[1]—Lawrence Addicks describes large-sized experiments upon these concentrates, the product of a mill using flotation, the copper mineral being chiefly chalcocite.

The concentrates were roasted in an 18-ft. MacDougall furnace, yielding a calcine containing Cu, 15.5 per cent.; Fe, 31; Al_2O_3, 5.6; S, 4 per cent. The 15 per cent. calcine was fed to a V-shaped trough where it was treated with a sulphuric acid solution of 5.6 per cent. at a temperature of 51° C., and, in the 60-sec. flow through the trough, the copper was brought down to 8 per cent., the extraction representing the instantaneously soluble copper. A Dorr classifier then took this residue, and by passing it six or eight times through the apparatus, brought the contents down to 3.5 per cent. copper, using a little over 2 lb. acid per pound of copper.

The residue, with addition of raw concentrates and 7.5 per cent. salt, was given a chloridizing roast at 525° C., and the resultant calcine leached in a liquor containing Na_2SO_4, 5 per cent.; NaCl, 5; $FeCl_2$, 5 and $HCl + H_2SO_4$, 0.5 per cent. The results show a 99 per cent. copper and 79 per cent. silver extraction.

The copper, in the first (the sulphate leach) might be precipitated by electrolysis or by iron, the second, from the chloridizing plant, by iron.

F. A. Flynn mentions the difficulties of transporting, and handling flotation concentrates and the losses in drying and roasting them. He thinks these might better be leached at the mill while raw and wet thus avoiding the losses specified. He is about to start experiments at Clifton, Ariz., to this end.

Calumet and Hecla Leaching Process.[2]—We refer to MINERAL INDUSTRY, **22**, 262 and **24**, 242. H. E. Williams gives additional particulars: At the plant eight only out of the sixteen 54-ft. tanks first proposed are used. Some 40 million tons of tailings from Torch Lake are being treated, after re-grinding, with a recovery of 8 lb. copper per ton from the 10½ lb. in the tailings, an extraction of 76 per cent. The first leaching solution now contains 1.5 per cent. each of NH_3 and CO_2. Delay in getting into full operation was due to the necessity of developing a roughing still.

2000-*Ton Leaching Plant at Anaconda.*[3]—The outline of the process is given in MINERAL INDUSTRY, **23**, 256. Briefly, sand tailing from an accumulated dump, after roasting, is treated to successive sulphuric acid washes in 50-ft. leaching tanks to extract the contained copper, and, with addition of salt, to remove silver. The dissolved copper and silver are precipitated by scrap iron.

The dump tailing, an accumulation of 20 million tons from the works

[1] *Bull. Amer. Inst. Min. Eng.*, Sept., 1916, p. 1565; Dec., 1916, p. 2160; *Min. Sci. Press*, **113**, 630.
[2] *Bull. Amer. Inst. Min. Eng.*, Dec., 1916, 2163.
[3] *Bull. Amer. Inst. Min. Eng.*, Aug., 1916, 1281; Dec., 1916, 2159.

concentrator since 1902, has an average copper content of 0.64 per cent. and of silver 0.48 oz. per ton. Of this, 0.15 per cent. is oxidized, the rest in sulphide form. The sands of 20-mesh size and less carry, with 5.6 per cent. moisture, 81 per cent. silica and 1.9 per cent. sulphur.

Referring to the flow sheet, Fig. 8, the V-bottom unloading bin, sunk beneath the ground track level has 22 gated openings supplying the 22 endless-belt cross-feeders which deliver to the conveyor system as shown. The large storage-bin has a double row of hoppers, 36 in all. At the apex of each hopper is a regulating gate when the sands flow, each upon its own cross-endless-belt feed, and these to a conveying-belt system to 20-ton sand bins one for each furnace. Adjoining the storage-bins are two hopper-bottom bins for coal and salt respectively. From the salt bin the salt is conveyed to a tall 25-ton feed-bin and thence to the conveyor system in the tank house to be used as needed in leaching. The same inclined conveyor also delivers coal to two 40-ton coal bins, and thence it is transported by larry to 4-ton hoppers, one for each four furnaces.

The steel furnace building, 232 by 110 ft., contains 28 MacDougall-type six-hearth furnaces, arranged in four rows of seven each. The furnace is 20 ft. in diam. and has opposite fire-boxes, the flame entering the third hearth. Endless-belt feeders deliver the sand from the 20-ton feed-hoppers through the feed-hole of the top arch upon the top floor. On the two upper hearths the sand is dried and heated, on the third the sulphur ignites the charge attaining a red heat, on the fourth it is of a dull red, on the fifth and sixth visible heat has disappeared.

There are two lines of 18-in. belt conveyors, one for each double row of 14 furnaces. Before delivery to these the calcine is cooled, then moistened. To accomplish this a revolving inclined cooling cylinder 30 in. in diam. by 19 ft. long parallel to the belt conveyors delivers the ore to a second cylinder at right angles, the ore then falling on the conveying belt. The first cylinder is lined with ¾-in. water-cooled pipes, while axially into the second cylinder is spurted a jet of water which dampens the ore to about 1 per cent. of moisture, thus preventing loss of dust in conveying. Flues for each row of furnaces, leading to a common balloon flue and thence to a 15 by 200-ft. steel stack, remove the furnace gases. Along the bottom of the balloon flue a 6-in. screw conveyor serves to remove the flue dust to one of the calcine conveyors. The furnace shaft and arms are air-cooled.[1]

The leaching building, 293 by 122 ft., is of steel and wood construction. It contains 10 redwood tanks, each 50 ft. in diam. by 14 ft. deep, to hold 1000 tons of calcine each, having the usual slotted false bottom covered by

[1] The tailing receives a simple oxidizing roast; the feed carries 2.2 per cent. sulphur, the calcine 0.6 per cent., and of this 0.2 per cent. is in the form of sulphate. The best results are obtained by carrying the heat on the fourth floor at 500° C.; the third hearth reaches 530° C.

17

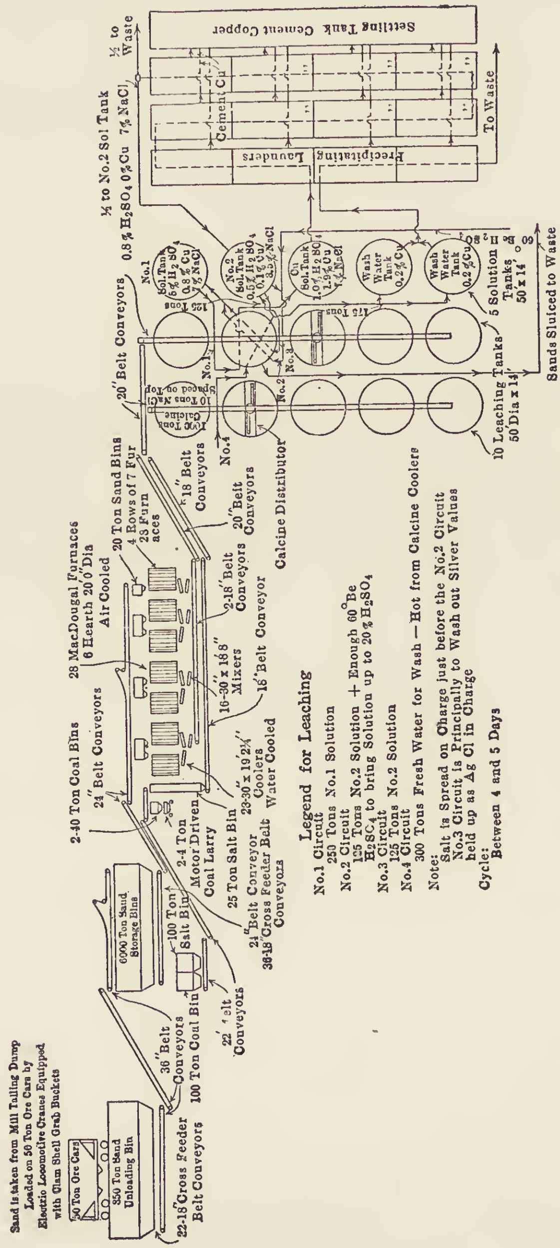


Fig. 8.—Flow sheet of leaching plant at Anaconda.

two layers of heavy cocoa matting, and this latter protected by a grating 3½ in. deep filled with the calcine. The steel tank hoops are covered with lead pipe as a protection against leaks of acid solutions.

Over each row of tanks is a 20-in. conveying belt with a tripper to deliver the calcines to a distributor. There are two travelling bridges, one over each row of tanks, and each bridge is set directly over the tank to be filled. The distributor, of 100 tons hourly capacity, is a framed truss hung at its center from the bridge and kept revolving about a vertical axis, so that its arms reach the periphery of the tank. The ore, falling from the tripper, is received on an endless-chain scraper-conveyor which moves it outward to the ends of arms. In so doing it drops the ore through openings regulated by slides to ensure even filling of the tanks as the distributor revolves. Leaching completed, the exhausted tailing is hosed out through seven bottom-discharge valves in about 8 hr. using two hose lines with 1½-in. nozzles. This tailing carries 0.082 per cent. copper and 0.14 oz. per ton of silver.

The leaching tanks, 50 ft. in diam. by 14 deep, are set 17 ft. lower than the floor of the leaching building. In a cycle of 120 hr., 8 hr. is devoted to emptying the leaching tank, 11 hr. to filling and 101 hr. to leaching. Solutions are returned to the leaching tanks by vertical shaft, direct connected to hard-lead centrifugal pumps.[1]

The flow sheet shows three lines of precipitating launders 250 ft. long, each row divided by partitions into four compartments, any one of which can be by-passed and separately cleaned out. The launders have a grated false bottom on which rests the scrap iron for precipitating. At the side of each section at the bottom are four 6-in. holes toward which the bottom slopes. These discharge by launders to the cement copper-settling tank. There the precipitate, of about 70 per cent. copper, is washed, stored, excavated by a clam-shell grab, and shipped to the briquetting plant before blast-furnace treatment.

The principal plant loss is due to dust made in roasting, so that actual recoveries amount to about 80 per cent. of the copper and 60 per cent. of the silver.

Something like 25 per cent. of the wash water taken out each day is sent over a special seat of precipitating tanks in order to keep down impurities.

New Cornelia Copper Co.[2]—The experimental work at Ajo, Ariz., described in Mineral Industry, **23**, 252, was completed Jan. 12, 1916.

[1] The percolation, which is downward, has a rate of 3 in. per hr. for the first solution and as high as 10 in. per hr. for the wash water. All solutions are maintained at 40° to 50° C. From a copper-solution tank there is but one outlet and that is to the precipitation launders. Two-thirds of the total flow from these launders (the so-called barren solution) is wasted, one-third goes back to No. 2 solution tank. This waste is necessary to keep the impurities such as iron and aluminium sulphates from building up in the solution.

[2] *Bull. Amer. Inst. Min. Eng.*, Sept., 1916, 1593; Dec., 1916, 2151; *Eng. Min. Jour.*, **102**, 530.

The experiments were made with a 1-ton and a 40-ton plant. From these a process was devised for a 5000-ton leaching plant as shown in the flow sheet, Fig. 9. An average of New Cornelia oxidized ore contains SiO_2, 65.7 per cent.; Al_2O_3, 15.3; Fe, 4.5; CaO, 0.6; MgO, 1.6; MnO, 0.14; Cu, 1.5 per cent., with but 0.005 oz. Au and 0.2 Ag per ton.

The crushing and leaching of the ore is sufficiently shown by the flow sheet. Fresh electrolyte from the electrolytic tanks passes to the leaching tank containing the oldest ore, that which has been leaching 7 days.

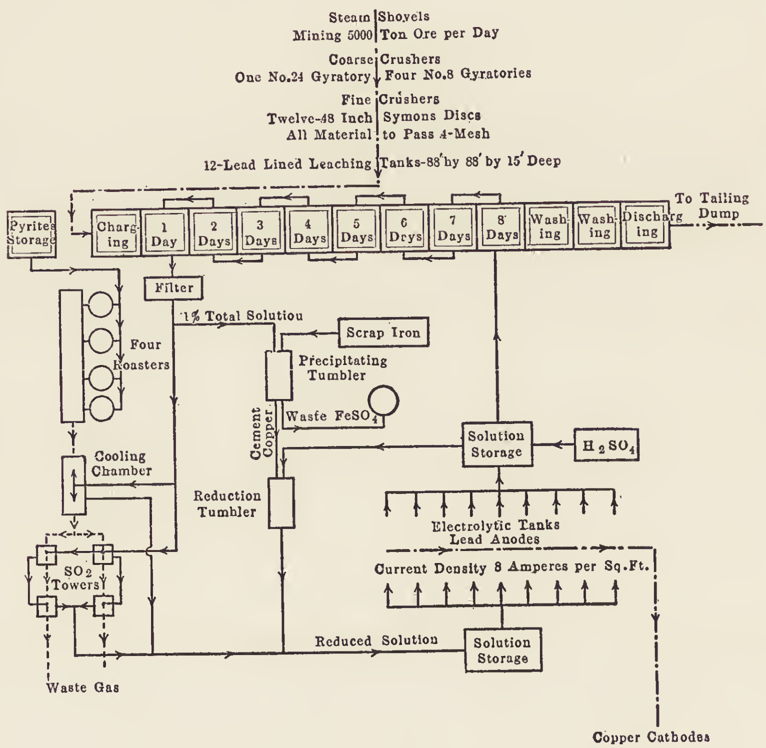


FIG. 9.—Flow sheet of leaching plant of New Cornelia Copper Co.

Practically neutral solution high in copper leaves the leaching system at the tank containing new ore. Between these two points is the advance from tank to tank. Neutral solution, leaving the last leaching tank, starts toward the electrolytic system. To obtain high extraction six out of the eight tanks are acid, the two others are neutral. After filtering, and to prevent fouling of the solution, 1 per cent. of it is removed and precipitated by the use of scrap iron, this being done in a precipitating tumbler or revolving barrel. The consequent mother liquor of $FeSO_4$ is wasted, while the cement copper is dissolved in another tumbler by aid of some of the acid electrolyte. This neutral copper-bearing solution joins the main flow. Returning now to that flow, this is pumped to four towers where it meets the upward-rising SO_2 gas. This gas is made by burning pyrites in four multiple-deck roasters which, after cooling, pass the towers in series, and the unabsorbed gas goes away at the top. The action of the SO_2 gas is to reduce the iron sulphate to the ferrous form, so that it may not precipitate in the electrolytic cells.

The electrolytic cells form a second closed circuit from which solution is by-passed continuously into the leaching system. To produce good coherent cathodes the cell circulation must be greater in volume than the neutral solution from the tanks. This is done by returning solution again to the cells after it has flowed through them. As will be noted from the flow sheet, lead anodes are preferred to those of graphite.[1]

As far as the tests show, the following results may be expected in the 5000-ton plant.

Extraction, using a closed wash cycle, 82 per cent.; by using extra wash water, 83 per cent. of the copper.

Acid consumption based on 100 per cent. H_2SO_4, 3 lb. of acid per lb. of copper at the outside. In the 1-ton plant as low as 1.65 lb. acid was found sufficient.

Power efficiency, 1 kw.-hr. per lb. of cathode copper.

Sulphur consumption, 0.5 lb. per lb. of copper.

Neutral solution only to pass through the reduction towers.

A bleeding or elimination of 1 per cent. of the total solution to prevent fouling. This 1 per cent., together with that dissolved in the reduction tumbler, will yield about 12 per cent. of the total copper.

This plant, with a capacity of 5000 tons daily, is expected to be in operation early in 1917 and to produce 36,000,000 lb. of copper per annum.

The Chuquicamata Leaching Works.[2]—This is the 10,000-ton plant of the Chile Exploration Co. at Chuquicamata, Chile, where brochantite is treated by leaching and with electrolytic precipitation of the copper-bearing solution.

Ore from the mine arrives on an approach trestle and passes first to two 84 by 60-in. jaw crushers now being put in. Dropping into 13,000-ton ore-bins, it is withdrawn by means of endless-chain feeders upon conveying belts to the crushing plant, there to be reduced to ½-in. mesh size. The

[1] Lawrence Addicks, in discussing the comparative merits of lead and carbon anodes, believes that the latter are destined to succeed lead anodes in the practical electrolysis of sulphate solutions. G. D. Van Arsdale specifies the advantages of carbon over lead anodes. These are that more than twice as much acid is regenerated with graphite as with lead. So, if lead anodes are used, an acid plant would be needed to supply the shortage of acid where more than 1½ lb. of acid is required per lb. of copper produced. The power needed for precipitation with lead is more than that for graphite.

By maintaining the ferric iron in the solution at less than 0.2 per cent., by blowing into it SO_2, the depreciation of carbon anodes may become negligible. Conditions there are obtainable of a yield of 3 lb. of copper per kw.-hr. at 12 amp. per sq. ft. To keep the ferric iron at the low figure specified a considerable tower capacity should be provided where the SO_2 gas may have time to react on the solution, also a more active circulation and some form of agitation should be practised in the cells.

[2] Trans. 2d Pan-American Sci. Cong.; *Met. Chem. Eng.*, **14**, 278; *Eng. Min. Jour.*, **101**, 321, 359; Mineral Industry, **22**, 870; **23**, 259; **24**, 249.

crushing plant comprises two No. 10 McCully gyratory crushers, and two 48-in. Symons disk-crushers and eight 54 by 20-in. high-speed rolls. Additional screens are to be put in to by-pass fine material around each crusher, and to return oversize to the roll crushers, so that the machinery may deliver the full tonnage of 10,000 tons per day. The crushed ore next goes to the sampling tower, where the sample of the total ore is taken.

The leaching plant comprises six rectangular leaching tanks marked, each tank 150 ft. long by 110 ft. wide. Parallel to the leaching tanks is a 36-in. conveying belt 1019 ft. long. The loading bridge is provided with a fixed tripper travelling with the bridge, which engages with the belt, and discharges on the conveyor belt on the bridge. This latter belt has a travelling tripper to insure even distribution of the ore in the tank. At the second vat a 6-ton clam-shell grab-bucket, suspended from the unloading bridge, removes the spent ore from the tank and delivers it to a belt which takes it to the tailings-disposal reversible conveyor opposite and parallel to the conveying belt. The leached ore is sampled as in the south tower, and then taken to the dump by transverse tailings conveyors.

We described filter tank construction in Mineral Industry, **24,** 249; we add that each tank has eight 6-in. outlet pipes spaced evenly over the tank bottom, and uniting into a 15-in. pipe-line which leads to the pump house. For conducting acid liquors, two sizes of lead-lined pipes, respectively 9 and 15 in. outside diam. are used, united by rubber gaskets 3/4 in. thick to allow for expansion of the pipe-lines.

The ore is leached in a 10,000-ton tank as in the following charge: Into a charge of 10,212 metric tons there was run 3300 tons of solution containing Cu, 3.48 per cent.; H_2SO_4, 6.8; Cl, 0.19 per cent., followed by solutions aggregating 14,500 tons, and varying in composition from 3.6 to 2.1 per cent. in copper, 6.9 to 2.0 per cent. in acid, and from 0.28 to 0.6 per cent. in chlorine. Then came 3300 tons of a weak solution having Cu, 0.8 per cent.; H_2SO_4, 0.64; Cl, 0.1 per cent. Finally came a water wash of 600 tons. All these operations took 9 days. There was drawn off a total of 21,000 tons of solution, which gradually fell from 4.8 to 1.1 per cent. copper at the last, while the acid dropped from 3.8 to 0.8 per cent. These various leaching solutions are stored in the solution sumps set at a higher level to command the leaching tanks.

A part of the last solution, containing 6 per cent. of the total copper withdrawn in each cycle, is removed for the complete deposition of its copper by means of scrap iron, then discarded. In this way there is no increase in the volume of the solutions, and impurities are also gotten rid of. These impurities are permitted to accumulate until the circulating solution carries Na_2SO_4, 15 per cent.; K_2SO_4, 1 per cent. and $MgSO_4$, 6.5 per cent., after which the discarded solution maintained the balance. Iron sulphate accumulates slowly, so that in 45 charges only 0.34 per cent. was found. Some nitric acid exists, but this is discarded with the other impurities. The sulphuric acid lost in discarding this solution is approximately equivalent to that gained from the copper sulphate in the ore, provided the ore contains not less than 2 per cent. copper. An acid-making plant has, however, been provided in case acid were needed.

From the strong solution sumps the solution is run to the de-chloridizing and filter-press plant. This contains 22 tube mills, each 4 ft. in diam. by 30 ft. long, with ½-in. steel shells lined with thin lead and with an inside shell of earthenware set in asphalt mastic. These mills are filled nearly half full of granulated copper with addition of cement copper, and revolved at 8 revolutions per min. The solution from the sump is divided into 22 streams, each to its own mill. The chlorine is precipitated as cuprous chloride. The chloride, in suspension, is carried in the flow to seven Dorr thickening tanks where the cuprous chloride settles out. The underflow from the thickeners, containing 50 per cent. moisture, is delivered to an Oliver filter. The filter-cake from this machine is delivered to the smeltery where it is mixed with limestone and coke and smelted in a blast furnace, black copper and calcium chloride slag being produced. To yield a supply of cement copper for the tube mill the cuprous chloride is now treated by being dissolved in a brine solution, and the copper precipitated by scrap iron. The iron consumed is but half that usually needed in treating copper solutions, since there is practically no acid present.

The clear solution from the thickening tanks is pumped to supply the electrolytic tank-house head-tank of 1815-cu. m. (500,000-gal.) capacity, and from this tank it flows by gravity to the electrolytic tank house (see also MINERAL INDUSTRY, **26**, 250).

The tank house has 448 tanks of reinforced cement lined with mastic, each tank being 19 ft. by 3 ft. 6 in. by 4 ft. 10 in. deep, arranged in 28 sections of 16 tanks, each section cascaded in one solution circuit. The cathodes are large, being 3 ft. by 4 ft. The entering solution carries 4.5 per cent. of copper, when leaving, 1.5 per cent. The current is 15 amp. per sq. ft. of cathode surface. Magnetite anodes were at first used in the electrolytic cells, but due to the impossibility of obtaining them from Germany, duriron has been substituted. This material is a silicon-iron alloy, and while acted on by the solutions, will last until 15 to 20 times its weight of copper has been deposited as the cathodes. Duriron anodes are mechanically stronger than magnetite, but need 15 per cent. more electrical energy to deposit the same amount of copper.

The copper refinery contains a blast furnace 40 by 60 in. at the tuyères, a 100-ton oil-fired anode furnace 26 ft. by 11 ft. with its casting machine, and a 168-ton wire-bar furnace, 41 by 14 ft. hearth dimensions, with its wire-bar casting machine.

Chuquicamata wire-bar copper has a conductivity of 100.5 to 101 per cent., Mathiesson's Standard.

CRYOLITE

The world's supply of cryolite comes entirely from the deposit at Ivigtut in Arauk Fjord, South Greenland. The mineral is found in other localities, notably around Pike's Peak in Colorado, but not in commercial quantities. The mineral is a double fluoride of sodium and aluminium, having the formula $3NaF.AlF_3$. Its use is principally as a fusible salt for electrolysis in the manufacture of aluminium, but some quantity is used also in opalescent glasses and enamels. The shipments from Greenland go only to the United States, where it is imported duty free by the Pennsylvania Salt Co., and to Copenhagen, Denmark, where it is imported by the Oresunds Chemiske Fabriker, the owners of the mine.

The deposit and the method of mining are described in MINERAL INDUSTRY, **24**, 254. The preparation for the market and uses are treated in MINERAL INDUSTRY, **20**, 263

The annual shipments from Greenland are as follows, in metric tons:

	To the United States.	To Copenhagen.	Total.
1913	1,964	8,451	10,415
1914	4,139	7,373	11,512
1915	3,753	5,809	9,562
1916	3,773	9,812	13,585

The Department of Commerce reports the following imports for the fiscal years ending June 30:

	Long Tons.	Value.	Value per Ton.
1913	2,519	$52,440	$20.80
1914	2,157	47,435	21.99
1915	4,569	91,417	20.01
1916	3,962	84,497	21.33

Nearly half of these imports are re-shipped to Canada, where aluminium is manufactured on a large scale. The Canadian imports, almost entirely from the United States, are as follows (for fiscal years ending March 31 of the succeeding calendar year):

	Short Tons.	Value.	Value per Ton.
1913	1,234	$50,905	$41.25
1914	1,075	44,683	41.56
1915	1,765	72,024	40.81
1916	860	87,146	101.33

FELDSPAR

By A. S. Watts

The feldspar industry had not changed materially during the past year. Operations in Mitchell and Yancey Counties, North Carolina, are increasing and The Clinchfield Products Co. has erected a mill at Erwin, Tenn., to grind feldspar from this district.

Renewed activity in the Adirondack quarries is also reported.

Increased activity in the feldspar quarries around Kingston, Ontario, is reported as due to the increased demand of soap and fertilizer manufacturers in the United States who can not obtain their potash from Europe as in former years. This Canadian feldspar is reported as analyzing: silica, 65.4 per cent.; alumina, 18.4 per cent.; potash, 13.9 per cent.; and soda, 2.0 per cent., and is practically free from quartz, which makes the feldspars of the United States undesirable for scouring-soap ingredient.

PRODUCTION OF FELDSPAR IN SHORT TONS

Years.	Crude.		Ground.		Total.	
	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.
1910	24,655	$81,965	56,447	$420,487	81,102	$502,452
1911	28,131	88,394	64,569	490,614	92,700	579,008
1912	26,462	89,001	60,110	431,561	86,572	520,562
1913	45,391	148,549	75,564	628,002	120,955	776,551
1914	85,905	263,476	49,514	366,397	135,419	629,873
1915	60,811	188,443	52,958	440,913	113,769	629,356
1916	84,185	251,372	48,496	450,906	132,681	702,278

The production of feldspar in the United States in 1916, as reported to the United States Geological Survey, was 132,681 short tons, having a value as crude material, f. o. b. mines, of $404,689. Of this amount 84,165 short tons entered the market as crude feldspar, valued at $251,372, and 48,496 short tons was ground by the producers and sold for $450,906. During the year the price of crude spar averaged about $3 per long ton and of ground spar about $9.30. Feldspar was mined in the following States, named in order of quantity produced by each: North Carolina, Maine, Maryland, New York, Connecticut, Pennsylvania, Georgia, Virginia, California, New Hampshire, Vermont. The output came chiefly from 50 quarries, but a like number of small or intermittently worked deposits contributed materially to the total.

Feldspar is used mostly in the pottery and enameling industries, which consumed 82 per cent. of the year's output. Probably less than 1, 2, and 3 per cent., respectively, of the total output were used for chicken grits, soap, and other abrasive purposes, and in making glass. Roofing and cement surfacing consumed about 7 per cent., and an equal proportion was used in preparing fertilizers and in the experimental extraction of potash.

A study of the fusion behavior of feldspar-calcite and feldspar-magnesite mixtures conducted by F. A. Kirkpatrick[1] indicates the following:

Between orthoclase (potash feldspar) and calcite, two well-defined deformation eutectics exist—one containing 3 per cent. calcite at 1261° C., and one containing 50 per cent. calcite at 1266° C. A well-defined deformation point maximum exists at 1353° C. with 27.5 per cent. calcite.

Between orthoclase and magnesite, a deformation eutectic exists at 1271° C. with 3 per cent. magnesite.

Between albite (soda feldspar) and calcite, a long eutectic range exists, extending from 10 to 55 per cent. calcite. If any definite deformation eutectic exists, it is at about 1157° C. and has about 25 per cent. calcite. The albite used in this study was very impure, containing 2.98 per cent. CaO, 1.0 per cent. K_2O, and 0.74 per cent. MgO. These impurities may prevent a definite eutectic being indicated, if one exists, either with calcite or magnesite.

Between albite and magnesite, a long eutectic range also exists but extends only from 10 to 20 per cent. magnesite. If a deformation eutectic exists, it is at 1185° C. and has about 15 per cent. magnesite.

The softening intervals of the mixtures, in general, have no relation to compositions, or to deformation temperature, indicating that the viscosity range is governed by several factors.

The results indicate that both orthoclase and albite are decomposed by CaO but not by MgO.

A study of the softening points of potash feldspar-steatite mixtures, conducted by W. S. Howat,[2] indicated that with commercial materials, the deformation eutectic mixture contains from 17½ to 22½ per cent. steatite, while with pure microcline the deformation eutectic proportions are 82½ per cent. feldspar and 17½ per cent. steatite.

A proposed standard method of classification of ground feldspar and flint is explained in detail by F. W. Walker, Jr.[3]

The process in brief is to take 100 gm. of sampled material dried at 100° C., mix with water in a large beaker and decant onto a 280-mesh standard brass sieve 8 in. in diameter. The material retained on the

[1] *Trans. Amer. Cer. Soc.*, **18,** 575.
[2] *Trans. Amer. Cer. Soc.*, **18,** 488.
[3] *Trans. Amer. Cer. Soc.*, **18,** 499

sieve is washed by submerging the sieve just so that the water will cover the product on the sieve, the wave-like motion of the water washing the material through the sieves as it moves back and forth. The residue is thoroughly dried at 75° C. on the sieve, which is placed over a 10-in. watch glass to prevent any loss, as the dry grains will pass through a smaller opening than when wet. The residual powder is then classified by a set of standard sieves of 115-, 150-, 170-, 200- and 280-mesh per linear inch. The shaking is done by a W. S. Tyler Co. Ro-Tap machine and continues for 69 min., after which a 1-min. test is made and the amount of material passing in that time determined. The residue on each sieve is weighed and recorded in per cent. of the original 100 gm.

The average of ten tests of white sand ground 8 hr. showed 36 per cent. coarser than 280-mesh.

The average of ten tests of white sand ground 9 hr. showed 23 per cent. coarser than 280-mesh.

The average of ten tests of white sand ground 10 hr. showed 9 per cent. coarser than 280-mesh.

The average of ten tests of white sand ground 14 hr. showed 3.7 per cent. coarser than 280-mesh.

Discussion brought out the fault of screen classification, which at best reports only on a small proportion of the total powdered material and neglects the finest portion, which is really most important. The data obtained is, however, a fair indicator of the degree of pulverization obtained and the process is recommended to users of feldspar as a standard test

FLUORSPAR

The production of fluorspar in the United States again broke all records in 1916, with an increase over 1915 of nearly 14 per cent. The amount is given by the U. S. Geological Survey as 155,735 short tons, compared with 136,941 in 1915, and the value as $922,654 against $764,475.

Imports also were larger, but are still only a quarter to a half of the annual imports before the war. However, the bulk of the supply has for several years been the domestic production, so that the stimulated production and high prices are due principally to the demands of the steel industry, rather than to foreign trade conditions.

PRODUCTION OF FLUORSPAR IN THE UNITED STATES, IN SHORT TONS

Year.	Quantity.	Value.	Year.	Quantity.	Value.
1901	19,586	$113,803	1909	50,742	$291,747
1902	48,018	271,832	1910	69,427	430,196
1903	42,523	213,617	1911	87,048	611,447
1904	36,452	234,755	1912	116,545	769,163
1905	57,385	362,488	1913	115,580	736,286
1906	40,796	244,025	1914	95,116	570,041
1907	49,496	287,342	1915	136,941	764,475
1908	38,785	225,998	1916	155,735	922,654

FLUORSPAR IMPORTED, IN SHORT TONS. (*a*)

	Quantity.	Value.	Average price per Ton.
1909	6,971	$26,377	$3.78
1910	42,488	135,152	3.18
1911	32,764	80,592	2.46
1912	26,176	71,616	2.74
1913	22,682	71,463	3.15
1914	10,205	38,943	3.82
1915	7,167	22,878	3.19
1916	10,499	52,976	5.05

(*a*) Statistics according to Bureau of Foreign and Domestic Commerce, Department of Commerce.

The value of the fluorspar at the mine is shown by the above figures to have increased from $5.58 per ton in 1915 to $5.92 in 1916. The market prices, however, have shown a much greater rise. In the fall metallurgical spar was bringing $12 per ton, about double the prevailing price in 1915, and at the close of the year it was quoted at $21 per net ton, carload lots. At the same time fluxing spar was quoted at $23 and acid at $25. Labor difficulties at the mines helped to boost the price.

The States producing fluorspar were the same as those in 1915—

Illinois, Kentucky, New Hampshire, New Mexico, and Colorado—and in addition South Dakota entered the list.

DOMESTIC FLUORSPAR SOLD, 1913-1915

State.	Gravel.			Lump.			Ground.			Total.		
	Quantity (Short Tons).	Value.	Average Price per Ton.	Quantity (Short Tons).	Value.	Average Price per Ton.	Quantity (Short Tons).	Value.	Average Price per Ton.	Quantity (Short Tons).	Value.	Average Price per Ton.
1913.												
Illinois.... Kentucky.	91,663	$525,456	$5.73	5,676	$39,059	$6.88	8,137	$100,203	$12.31	85,854 19,662	$550,815 113,908	$6.42 5.80
Other States (a).	b 10,104	71,568	7.08	(b)	(b)	......	....	....	......	10,104	71,568	7.08
	b101,767	597,024	5.87	5,676	39,059	6.88	8,137	100,203	12.31	115,580	736,286	6.37
1914.												
Illinois.... Kentucky.	77,048	397,913	5.16	8,842	74,708	8.45	6,998	82,428	11.78	73,811 19,077	426,063 128,986	5.77 6.76
Other States (a).	b 2,228	14,992	6.73	(b)	(b)	......	....	....	......	2,228	14,992	6.73
	b 79,276	412,905	5.21	8,842	74,708	8.45	6,998	82,428	11.78	95,116	570,041	5.99
1915.												
Illinois.... Kentucky.	112,769	547,415	4.85	12,033	90,337	7.51	10,757	116,161	10.80	135.559	753,913	5.56
Other States (a).	b 1,382	10,562	7.64	(b)	(b)	......	....	....	......	1,382	10,562	7.64
	b114,151	557,977	4.89	b12,033	90,337	7.51	10,757	116,161	10.80	136,941	764,475	5.58

(a) Includes, 1913: Arizona, Colorado, New Hampshire, and New Mexico; 1914: Colorado and New Hampshire; 1915: Colorado, New Hampshire, and New Mexico.
(b) Some lump spar is included with gravel.

Foreign Countries.—Great Britain is the most important of the foreign producers. The producing centers there were discussed at some length in Mineral Industry **24,** 260-262 (1915). The amount of the production in Great Britain in long tons is as follows: 1916, 34,547; 1915, 33,123; 1914, 33,816; 1913, 53,663.

Canada.—Shipments of fluorspar were made from Madoc, Ont., during 1916 amounting to 1284 tons, valued at $10,238. This was practically the first commercial operation of these deposits.

Before the war Germany had an annual production of about 20,000 tons, Austria-Hungary 8000 tons, and France from 6000 to 10,000. Recent statistics are not available from these countries. There were no other important producers.

FULLER'S EARTH

By E. H. Sellards

The total production of fuller's earth in the United States during 1916 was 67,822 short tons, an increase over the preceding year of 19,921 tons. In addition to that produced there was imported into the United States during 1916, 15,001 short tons. Some fuller's earth is exported from the United States, although the amount can not be determined owing to the fact that this product is not listed separately from other clays.

The States producing fuller's earth during 1916 were Arkansas, California, Florida, Georgia, Massachusetts and Texas. Of these Florida is the chief producer, the output from this State amounting to more than three-fourths of the whole output for the United States. The value of the fuller's earth produced in the United States during 1916 was $706,951, an increase of 45 per cent. The average price per ton was 21 cts. higher than in 1915.

STATISTICS OF FULLER'S EARTH IN THE UNITED STATES
(In tons of 2000 lb.)

Year.	Production.		Imports.		Year.	Production.		Imports.	
	Sh. Tons.	Value.	Sh. Tons.	Value.		Sh. Tons.	Value.	Sh. Tons.	Value.
1904......	29,480	$168,500	10,221	$74,000	1911......	34,668	$335,350	18,224	$143,594
1905......	25,745	157,776	15,181	105,997	1912......	32,715	305,522	19,109	145,337
1906......	28,000	237,950	14,827	108,696	1913......	38,594	369,750	18,628	145,588
1907......	34,039	323,275	14,648	122,221	1914......	40,981	403,646	24,974	195,083
1908......	30,517	270,685	12,279	93,413	1915......	47,901	489,219	19,441	152,493
1909......	29,561	289,000	12,752	101,151	1916......	67,822	706,951	15,001	139,664
1910......	30,857	277,293	16,857	132,545					

Clays having the properties of fuller's earth more or less well developed are widely distributed in the United States and are confined to no particular geological horizon, although the largest known deposits are of Cenozoic age. By far the greater part of fuller's earth is in the form of a sedimentary deposit which is distinctly stratified, and from which an overburden must be removed in mining.

Fuller's earth obtains its name from its original use in fulling cloth. Little domestic earth is now used in this country for that purpose, the principal use being in bleaching, clarifying, or filtering fats, greases, and oils. It is also used in the manufacture of pigments for printing wall papers, for detecting certain coloring matters in some food products and as a substitute for talcum powder.[1]

[1] U. S. Geol. Surv.

GOLD AND SILVER

By M. W. von Bernewitz

The past year will be recorded in economic history as a remarkable one, due to the war, in which 14 nations are engaged. At the end of 1916 there was considerable peace talk, but the outlook is not bright for this desired end. The United States (now at war) did an enormous business. Export trade—up to $510,000,000 in 1 month—more than doubled in value in 1916 over 1913. All neutral countries' trade increased largely, and even the trade of those who are fighting, save the Central Powers. Total American exports for the year approximate $5,500,000,000, and imports $2,400,000,000. To reconcile this activity with a gigantic conflict appears a difficult task in theory, yet it is so. Gold and silver movements were tremendous, the New York Assay Office at times being "flooded" with the yellow metal. Imports of gold totalled $684,700,000, compared with $451,954,590 in 1915, and $57,387,741 in 1914. Exports of gold in 1916 were $142,800,000 against $31,425,918 in 1915, and $222,616,156 in 1914. The 1916 imports were by far the greatest quantity to enter the United States in a single year. Since the beginning of the war (August, 1914), total gold imports were $1,100,000,000, less $275,000,000 exported. During this period American mines yielded over $200,000,000, in gold, so that in 29 months the stock of yellow metal in the United States increased by about $1,000,000,000. The war had a great effect on the commercial movement of gold. The United States has lent over $1,900,000,000, since the war started. The business done in all lines was tremendous in 1916, and the industrial capacity of the country is sold up until late in 1917. Bank clearings in America totaled $258,756,061,695, compared with $187,809,779,542 in 1915. In New York the total was $168,526,456,133, against $116,544,965,371 in the previous year. The Stock Exchange also had a record year, transactions amounting to $1,158,209,000, an increase of $206,420,000. Only in 1901, 1905, and 1906 has the 1916 total been exceeded. Of course, trading in "war babies," especially during the last quarter, was responsible for most of the increase.

GOLD AND SILVER PRODUCTION OF THE WORLD, 1493–1850
According to Dr. Adolph Soetbeer

Period.	Estimated Production in Kilograms.		Ratio of Silver to Gold. Weight.	Ratio of Gold to Silver. Value.	Period.	Estimated Production in Kilograms.		Ratio of Silver to Gold. Weight.	Ratio of Gold to Silver. Value.
	Gold.	Silver.				Gold.	Silver.		
1493–1520	162,400	1,316,000	8.1	10.75	1701–1720	256,400	7,112,000	27.7	15.21
1521–1544	171,840	2,164,800	12.6	11.25	1721–1740	381,600	8,624,000	22.6	15.08
1545–1560	136,160	4,985,600	36.6	11.30	1740–1760	492,200	10,662,900	21.7	14.75
1561–1580	136,800	5,990,000	43.8	11.50	1761–1780	414,100	13,054,800	31.5	14.73
1581–1600	147,600	8,378,000	56.8	11.80	1781–1800	355,800	17,581,200	49.4	15.09
1601–1620	170,400	8,458,000	49.6	12.25	1801–1810	177,780	8,941,500	50.3	15.61
1621–1640	166,000	7,872,000	47.4	14.00	1811–1820	114,450	5,407,700	47.2	15.51
1641–1660	175,400	7,326,000	41.8	14.50	1821–1830	142,160	4,605,600	32.4	15.80
1661–1680	185,200	6,740,000	36.4	15.00	1831–1840	202,890	5,964,500	29.4	15.75
1681–1700	215,300	6,838,000	31.8	14.97	1841–1850	547,590	7,804,150	14.3	15.83

GOLD PRODUCTION OF THE WORLD, 1851–1916

Year.	Value.	Year.	Value.	Year.	Value.	Year.	Value.
1851...	$67,600,000	1871...	$107,000,000	1891 ..	$130,650,000	1911...	$464,346,495
1852....	132,800,000	1872...	99,600,000	1892...	146,292,600	1912...	474,322,664
1853....	155,500,000	1873...	96,200,000	1893...	158,437,551	1913...	462,669,558
1854....	127,500,000	1874...	90,800,000	1894...	182,509,283	1914...	455,676,600
1855....	135,100,000	1875...	97,500,000	1895...	198,995,741	1915...	476,208,000
1856....	147,600,000	1876 ..	103,700,000	1896...	211,242,081	1916...	467,000,000
1857....	133,300,000	1877...	114,000,000	1897...	237,833,984	....	....
1858....	124,700,000	1878...	119,000,000	1898...	287,327,833	....	....
1859....	124,900,000	1879...	109,000,000	1899...	311,505,947	....	....
1860....	119,300,000	1880...	106,600,000	1900...	258,829,703	....	....
1861....	113,800,000	1881...	103,102,000	1901...	260,877,429	....	....
1862....	107,800,000	1882...	102,000,000	1902...	298,812,493	....	....
1863....	107,000,000	1883...	95,400,000	1903...	329,475,401	....	....
1864....	113,000,000	1884...	101,700,000	1904...	349,088,293	....	....
1865....	120,200,000	1885...	108,400,000	1905...	378,411,754	....	....
1866....	121,000,000	1886...	106,000,000	1906...	405,551,022	....	....
1867....	104,000,000	1887...	105,775,000	1907...	416,101,396	....	....
1868....	109,700,000	1888...	110,197,000	1908...	443,355,856	....	....
1869....	106,200,000	1889 ..	123,489,000	1909...	458,424,058	....	....
1870....	106,900,000	1890...	118,848,700	1910...	453,766,523	....	....

SILVER PRODUCTION OF THE WORLD, 1856–1916

Year.	Kilograms.	Year.	Kilograms.	Year.	Kilograms.	Year.	Kilograms.
1856–1860 .	4,534,950	1884....	2,788,727	1896.....	5,496,178	1908.....	6,612,304
1861–1865 .	5,505,575	1885....	2,993,805	1897.....	5,663,304	1909.....	7,069,656
1866–1870 .	6,695,425	1886....	2,902,471	1898.....	5,575,336	1910.....	7,471,663
1871–1875 .	9,847,125	1887....	2,990,398	1899.....	5,529,024	1911.....	7,906,446
1876.......	2,323,729	1888....	3,385,606	1900.....	5,599,216	1912.....	7,804,516
1877.......	2,388,612	1889....	3,901,809	1901.....	5,438,443	1913.....	6,964,361
1878.......	2,551,364	1890....	4,180,532	1902.....	5,121,469	1914.....	5,201,959
1879.......	2,507,507	1891....	4,479,649	1903.....	5,386,044	1915.....	5,591,104
1880.......	2,499,998	1892....	4,985,855	1904.....	5,669,124	1916.....	(*e*)5,517,000
1881.......	2,592,639	1893....	5,339,746	1905.....	5,638,183		
1882.......	2,769,065	1894....	5,205,065	1906.....	5,683,947		
1883.......	2,746,123	1895....	5,667,691	1907.....	5,704,083		

(*e*) Estimated. 1 kilogram = 32.15 Troy ounces.

GOLD PRODUCTION OF THE WORLD

Countries.	1914.			1915.			1916.		
	Oz. Fine.	Kilograms.	Value.	Oz. Fine.	Kilograms.	Value.	Oz. Fine.	Kilograms.	Value.
America, North:									
United States....	(*d*)4,572,976	139,731	$94,531,800	(*a*)4,887,604	157,158	$101,035,700	(*a*)4,465,807	139,600	$92,316,400
Canada....	(*a*)773,178	23,962	15,983,007	916,076	28,494	18,936,971	927,000	29,000	19,162,000
Mexico....	231,628	7,205	4,788,175	317,305	9,870	6,559,275	604,600	18,800	12,500,000
Central America..	115,771	3,601	2,393,190	143,687	4,469	2,970,271	....	......	....
America, South:									
Argentina .	....	......	....	....	......	....	....	......	....
Bolivia....	(*b*)9,809	305	202,770	39,397	1,225	814,418	....	......	....
Brazil.....	(*d*)130,525	4,060	2,698,192	117,286	3,648	2,424,515	....	......	....
Chile......	....	......	....	....	......	....	....	......	....
Colombia..	(*d*)226,326	7,040	4,678,000	263,796	8,205	5,453,148	....	......	....
Ecuador...	(*e*)14,512	451	300,000	26,397	821	545,674	....	......	....
Guiana, British...	(*d*)54,495	1,695	1,126,515	50,615	1,574	1,046,300	....	......	....
Guiana, Dutch....	(*d*)24,351	757	503,400	21,723	676	449,054	....	......	....
Guiana, French...	94,805	2,949	1,959,793	94,805	2,949	1,959,793	....	......	....
Peru......	49,445	1,538	1,022,125	53,691	1,670	1,109,891	....	......	....
Uruguay...	739	23	15,276	573	18	11,836	....	......	....
Venezuela .	29,644	922	612,796	29,644	922	612,796	....	......	....
Europe:									
Austria....	(*e*)9,711	302	200,744	9,711	302	200,744	....	......	....
France....	(*e*)70,144	2,182	1,450,000	67,725	2,107	1,400,000	....	......	....
Hungary ..	(*e*)84,656	2,633	1,750,000	....	......	....	....	......	....
Germany..	....	......	....	....	......	....	....	......	....
Italy......	(*a*)1,191	38	21,589	111	3	2,295	....	......	....
Russia.....	1,382,900	43,014	28,587,025	1,412,533	43,936	29,199,600	1,500,000	47,000	31,000,000
Portugal...	113	4	2,336	32	1	661	....	......	....
Sweden....	2,627	82	54,304	1,090	37	22,532	....	......	....
Turkey....	23	1	475	23	1	475	....	......	....
Servia.....	(*d*)4,533	141	115,991	....	......	....	....	......	....
United Kingdom.	(*d*)979	30	20,238	932	29	19,266	....	......	....
Africa:									
Congo.....	(*e*)43,537	1,354	900,000	87,224	2,713	1,804,000	82,000	2,500	1,700,000
Madagascar....	53,213	1,655	1,100,000	42,242	1,314	973,300	40,000	1,250	830,000
Rhodesia..	(*a*)854,480	26,578	17,423,087	915,029	29,422	18,914,000	915,000	29,000	18,912,000
Transvaal .	(*a*)8,378,139	260,595	173,189,367	9,093,769	282,854	187,984,400	8,972,000	280,400	191,502,000
West Coast	(*e*)419,510	13,049	8,404,660	412,273	13,256	8,303,698	380,000	12,000	7,860,887
Asia:									
Borneo, British...	(*e*)62,387	1,940	1,289,650	63,564	1,977	1,319,000	59,000	1,800	1,215,000
British India.....	(*d*)550,432	17,120	11,378,437	557,111	17,328	11,516,600	540,000	17,000	11,153,000
China.....	(*e*)175,360	5,454	3,625,000	177,744	5,529	3,674,300	177,000	5,400	3,650,000
E. Indies, British... } Dutch.... }	(*e*)226,879	7,057	4,690,000	157,733	4,906	3,260,600	....	......	....
Indo-China	3,213	100	66,419	2,112	66	43,659	....	......	....
Formosa...	46,092	1,434	952,806	55,293	1,720	1,143,017	....	......	....
Japan.....	(*e*)216,551	6,736	4,476,500	260,504	8,104	5,385,917	} 532,000	16,600	11,000,000
Korea.....	(*e*)160,115	4,980	3,309,870	180,897	5,627	3,739,477	}		
Malay States....	(*d*)13,020	405	269,100	17,005	529	351,524	17,000	530	350,000
Siam......	....	......	....	....	......	....	....	......	....
Australasia(*c*)	(*e*)2,414,674	75,106	49,915,336	2,298,372	73,903	48,067,570	1,980,000	62,000	40,392,700
Total....	(*d*)21,240,416	660,667	439,078,260	22,758,808	707,897	470,466,214	....	......	....

(*a*) Official statistics of the country. (*b*) Bolivia and Chile. (*c*) Six states and New Zealand. (*d*) Report of the Director of the U. S. Mint, 1915. (*e*) Estimated.

The circulation of money in the United States rose from $37.51 per capita in November, 1915, to $40.62 in that month of last year. The huge quantity of gold in the country is not received with pleasure by financiers. Economists and publicists long ago recognized that accumulation of excessive supplies of gold in a country is detrimental to its foreign trade, indeed, may prove a menace to real prosperity. George E. Roberts of the National City Bank of New York says that the effect of gold importations is to cause a still higher level of wages and prices. Capital is increasing faster than the population and labor to employ it, which is a beneficial condition in normal times, but not under the present temporary conditions. Readjustment becomes more difficult as the situation continues. A. C. Miller of the Federal Reserve Board, writing to *The Annalist*, says that the financial mind of the country is in a state of some unsettlement and perplexity in the face of the unprecedented crisis of prosperity which has been confronting us. One of the dangers is the difficulty and embarrassment that would attend the inevitable return, on the restoration of peace, of the excess gold we have received from Europe, unless some means of controlling and regulating its flow should be devised. The past year intensified this situation. The continuous influx of gold might be termed our "yellow peril."

T. H. Lamont, of J. P. Morgan & Co., and Elbert G. Gary, of the U. S. Steel Corporation, were among those who advised caution in this connection.

While the United States has been piling up gold, received in payment for interest on loans, etc., and for products sold, the nations at war are doing likewise. A comparison of gold holdings by the great banks at the end of the past three years is as follows:

	1916.	1915.	1914.
Bank of England	£55,306,548	£50,281,182	£72,414,101
Bank of France (francs)	5,065,012,000	4,026,400,000	4,141,350,000
Bank of Germany (marks)	2,518,758,000	2,436,200,000	2,018,440,000
Bank of Russia (rubles)	1,556,040,000	1,595,640,000	1,621,460,000

As a medium of exchange, gold is comparatively scarce in Europe, and will remain so until the end of the war. This has affected the silver market, as will be discussed later in this review. While the gold output of the world was $476,000,000 in 1915, it is certain that in 1916 it was not over $470,000,000. This was not due to mines being closed on account of the war, but simply due to the lower yields from several large mines and districts as they are approaching exhaustion. In other places there were increased yields. The great demand for gold makes it imperative that the output of the world be maintained or expanded. How is this to be done? Of the possibilities in Africa, Asia, and North America, there is one region offering early returns if work is started now, and that is the Far East Rand. In the review of mining following, the problems on the Rand are given considerable space; but this is warranted. In fact, the review this year does not so much deal with the settled gold- and silver-producing centers, as with the possibilities of newer districts, therefore the Far East Rand, northern Ontario, Russia, and South America receive extra consideration.

During the last 25 years the world's gold production equaled that of the preceding 400 years, and the silver production since 1878 equaled that of the previous 4 centuries. The gold money of the world has doubled in the last 20 years ($4,144,000,000 to $8,258,000,000) while the silver money decreased 50 per cent. in the same period ($4,144,000,000 to $2,441,000,000).

The economic conditions now prevailing are not favorable to gold mining, except in so far as the accumulation of capital leads to new enterprise.[1] The value of gold, although fixed by convention, has depreciated considerably of late, as proved by the fact that a given weight of it will buy 30 per cent. less of the principal commodities than a year ago. The cost of supplies and machinery, more particularly the use of man, the essential machine, has risen 25 to 33 per cent. A higher rate of wages has been forced on the managements of gold mines because the base-metal mining companies have granted a raise to their employees and also because the increasing cost of living leaves the workman a diminishing margin on the safe side. Labor troubles have been few, mainly because sagacious managers have anticipated the inevitable demand, but readjustment after the war is sure to involve friction.

Dividends paid by 39 gold- and silver-mining companies during 1916 amounted to $12,000,000, of which $5,000,000 was paid by three companies, namely, the Cresson of Cripple Creek, Homestake of South Dakota, and Yukon Gold of the Klondike. Several well-known producers either paid nothing or reduced their disbursements.

The hoarding of gold, as it were, by the European powers, and the consequent circulation of largely increased quantities of silver coin, has resulted in a strong demand for silver. The market during 1916 was good, and the average price was 16 cts. higher than in 1915. At present quotations are firm around 76 cts. per ounce, and it is quite possible to have dollar silver during 1917. The silver situation is important, and the following review[2] by one of the world's leading bullion brokers is a valuable record:

[1] *Min. Sci. Press*, **114**, 6 (1917).
[2] Abstract from Annual Bullion Letter of Samuel Montagu & Co., London.

Briefly the following factors affected the market during the past year:

Month.	Average Price per Ounce.		Factor.
	New York, Cents.	London, Pence.	
January........	56.775	26.960	General coinage demand for Allied and neutral nations.
February.......	56.755	26.975	
March..........	57.935	27.597	Indian Mint starts to buy.
April...........	64.415	30.661	Heavy shipments from China.
May...........	74.269	35.476	Great reduction in Indian Treasury silver reserves.
June...........	65.024	31.060	Less competition from Allied Governments.
July...........	62.940	30.000	
August.........	66.083	31.497	United States loan to China, part remitted in silver.
September......	68.515	32.584	Demand for U. S. Mint.
October........	67.855	32.360	Some speculative activity for the rise.
November......	71.604	34.187	Cessation of China sales.
December.......	75.765	36.410	Indian Mint a keen buyer.

These prices were for cash delivery, there being no quotations for 2 months' delivery.

The year opened with fair prospects for silver. Coinage for Allied and neutral European nations was in operation, and a steady continuous pressure was being exerted upon the world's supplies in order to fill currency demands in England and abroad, which became keener as the year wore on. During the first 2½ months the price kept within ⅝d. (1¼ cts.) of 26 11/16d. (53⅜ cts.). The reluctance of prices to rise, notwithstanding the strength of the market, was attributable to sales of silver on account of China, where the visible accumulations of metal were large. The Indian

AVERAGE PRICE OF BAR SILVER IN LONDON
(In pence per standard ounce, 925 fine)

Year.	Pence.	Year.	Pence.	Year.	Pence.	Year.	Pence.	Year.	Pence.	Year.	Pence.	Year.	Pence.
1840.	60.3750	1850	60.0625	1860	61.6875	1870	60.5625	1880	52.2500	1890	47.6875	1900	28.2500
1841.	60.0625	1851	61.0000	1861	60.8125	1871	60.5000	1881	51.6875	1891	45.0625	1901	27.1875
1842.	59.4375	1852	60.5000	1862	61.4375	1872	60.3125	1882	51.6250	1892	39.8125	1902	24.0900
1843.	59.1875	1853	61.5000	1863	61.3750	1873	59.2500	1883	50.5625	1893	35.6250	1903	24.7500
1844.	59.5000	1854	61.5000	1864	61.3750	1874	58.3125	1884	50.6250	1894	28.9375	1904	26.3990
1845.	59.2500	1855	61.3125	1865	61.0625	1875	56.8750	1885	48.6250	1895	29.8750	1905	27.8390
1846.	59.3125	1856	61.3125	1866	61.1250	1876	52.7500	1886	45.3750	1896	30.7500	.....	....
1847.	59.6875	1857	61.7500	1867	60.5625	1877	54.8125	1887	44.6250	1897	27.5625	.....	....
1848.	59.5000	1858	61.3125	1868	60.5000	1878	52.5625	1888	42.8750	1898	26.4375	.....	....
1849.	59.7500	1859	62.0625	1869	60.4375	1879	51.2500	1889	42.6875	1899	27.4375	.....	....

Year.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
1906....	30.113	30.464	29.854	29.984	30.968	30.185	30.113	30.529	31.483	32.148	32.671	32.003	30.868
1907....	31.769	31.852	31.325	30.253	30.471	30.893	31.366	31.637	31.313	28.863	27.154	25.362	30.188
1908....	25.738	25.855	25.570	25.133	24.377	24.760	24.514	23.858	23.877	23.725	22.933	22.493	24.402
1909....	23.843	23.706	23.227	23.708	24.343	24.166	23.519	23.588	23.743	23.502	23.351	24.030	23.706
1910....	24.154	23.794	23.690	24.483	24.797	24.651	25.034	24.428	24.567	25.596	25.680	25.160	24.670
1911 ...	24.865	24.081	24.324	24.595	24.583	24.486	24.286	24.082	24.209	25.594	25.649	25.349	24.592
1912....	25.887	27.190	26.875	27.284	28.038	28.215	27.919	28.375	29.088	29.299	29.012	29.320	28.842
1913....	28.993	28.356	26.669	27.415	27.794	27.195	27.074	27.335	27.985	28.083	27.262	26.720	27.573
1914....	26.553	26.573	26.788	26.958	26.704	25.948	25.219	25.979	24.260	23.199	22.703	22.900	25.313
1915....	22.731	22.753	23.708	23.709	23.570	23.267	22.597	22.780	23.591	23.925	25.094	26.373	23.675
1916....	26.960	26.975	27.597	30.662	35.477	31.060	30.000	31.498	32.584	32.361	34.192	36.410	31.315

Bazaars betrayed only an intermittent interest, not of an active character. Meanwhile a persistent decrease in the holding of silver rupees by the Indian Treasuries indicated that purchases would have to be made ere long for the Indian Mints. The war had imposed an unusual strain upon the stock of rupees. In three great theatres of the war—Mesopotamia, East Africa, and Egypt—these coins were in exceptional demand. In the last-named country the rupee was made legally current as a temporary expedient, until such time as sufficient piastres could be minted and put into circulation to meet the need of the troops. The large quantity of rupees that have obtained a fresh domicile, especially those in Mesopotamia, will not be quickly repatriated. Circulating among the Arabs and other denizens of countries bordering upon the Persian Gulf, they have filtered into the interior, where silver currency, hitherto somewhat of a luxury, is welcome. An urgent demand for new currency in Australia, owing to the activity of war industries, led to an arrangement for silver yielded by Australian mines to be minted in the Commonwealth, so as to relieve the Royal Mint at London, fully occupied with British coinage. In the third week of March, a shipment of £350,000 was announced from China to India, and a sharp change came over the market. The stock of rupees in the Indian Treasury was 2806 lacs (1 lac = $32,000) on Dec. 31, 1915. By March 22, 1916, the total had fallen without a break to 2215 lacs; hence there was little doubt that the shipment was made on account of the Indian government. The price at once sought a new level, reaching $28^{15}/_{16}$d. on March 24, and hovered in that neighborhood until the beginning of April, when a fresh upward movement began. Notwithstanding substantial purchases of silver in China, and also in London, the drain of rupees from the Indian Treasuries still continued until on Dec. 22 the total was only 1623 lacs, a decrease of 1183 ($37,856,000) in a year. The note circulation meanwhile increased from 6297 to 7963 lacs. During April, currency demand became increasingly active for the Continent as well as for the Indian and British mints. The last-mentioned continued to find difficulty in coping with local needs. The healthy condition of the market encouraged speculative purchases on the part of the Indian Bazaars and elsewhere. The impetus generated by enquiries, so varied and constant, carried the price to 30d. within a fortnight, and to $31^{3}/_{16}$d. within 3 weeks, and from this point until May the market developed remarkable strength. The highest quotation in 1916—$37^{1}/_{8}$d.—and the highest since 1893 was on May 3. It may be here observed that the great reduction in supplies from Mexico, where unrest has seriously hampered mining operations, especially in the northern districts, accentuated the difficulty of meeting the unusually urgent requirements that had arisen. Further, the undefined political situation in China prevented the trade of that country from acting as a counterpoise to silver in accordance with custom. High silver prices acting upon the China exchanges formerly had the effect of encouraging automatically foreign imports to a degree somewhat commensurate with the rise in rates, but internal conditions in China and the difficulty of shipping were not favorable to foreign imports. Therefore, the release of silver from China represented rather a transfer of capital than a transfer of trade. Hence the link between silver and the China exchanges failed to check the headlong course of the market. Some new sources of supply were tapped. Certain current coins, such as Mexican, Philippine, Maria Theresa dollars, etc., became worth more dead than alive. After a healthy reaction the price again mounted as high as 37d. on May 12. On the 15th, the total of silver—coined and uncoined—in the Indian reserves fell to 1771 lacs, the lowest figure recorded since Jan. 24, 1914. This had much to do with the strong tendency of the silver market, for the currency figures are always closely watched by the Indian Bazaars. Not without reason, for they afford a reliable barometer—and a fall to 1800 lacs has been considered by authorities as danger point. The reduction below the total hitherto considered advisable naturally encouraged speculative buyers, and the quotation kept at 36d. or over until May 20. An arrangement having been made to avoid unnecessary competition between mintage orders, the Indian Bazaars—at the time large speculative holders—took alarm, sold heavily, and by so doing, depressed the price instantly to 34d. on May 22. The decline continued, despite temporary rallies caused by spasmodic spells of speculation, until 28⅝d. was quoted on July 10. Throughout this period the Indian government, assisted by falling China exchanges, was able to replenish its reserves with such success that the Indian Bazaars, becoming obsessed with unfavorable views, not infrequently made bear sales in the London market. For the next 2½ months the inclination of prices was steadily upward. A loan by the United States to China reduced supplies from America to the open market, inasmuch as about 1,000,000 oz. was remitted in silver. On the other hand, China sold frequently either to the Indian Mint, the Bazaars, or London. Throughout October the price remained steady. Meanwhile the United States Mint absorbed some of the local supplies. The stock in Shanghai continued to shrink, and the China exchanges began to approximate the par of silver, suggesting that China had released about as much silver as could be spared, in view of the growing activity of its exports. Early in November the tables were turned, China ceased selling and commenced buying. The new factor was felt at once. The price rose rapidly, and after a slight reaction the advance was resumed until 36d. was recorded on Dec. 2. The price remained about this figure for a few days and then again took an upward course, which carried it to 37d. on the 15th. This figure was attained the day after the Indian government announced that its allotments of Bills and T.T. would be confined to the amounts offered for tender. The main factor in these rising prices was the continuous and heavy withdrawal of rupees from the Indian Treasury. In the latter half of December a considerable quantity of silver—reported as over £1,000,000 in value—was acquired for the Indian Mint at Bombay and Calcutta. The pressure being somewhat relaxed, prices eased off toward the close of the year.

Appended will be found the apparent stocks of bar silver at the close of 1916 as closely as can be ascertained, together with corresponding figures for the 3 preceding years, in ounces:

	1916.	1915.	1914.	1913.
Shanghai	not reported	720,000	500,000	2,660,000
Bombay	2,420,000	6,900,000	5,000,000	1,320,000
At sea	[1]1,400,000	3,125,000	1,500,000	2,000,000
London	6,350,000	6,800,000	11,000,000	15,800,000
Total	10,170,000	17,545,000	18,000,000	21,780,000

[1] Exclusive of silver consigned to the Indian Government.

The totals of sycee (60-oz. shoe-shaped bars) at Shanghai for the four periods were 1916, 23,900,000 oz.; 1915, 62,100,000 oz.; 1914, 68,000,000 oz.; and 1913, 50,300,000 oz.

Two circumstances are of interest in connection with the shipment of silver from China. First, that the demand for remittances to London was large and continuous, and evidently independent of the movement of trade. The likeliest solution is that foreigners in China have been transmitting unusually large amounts of capital from China to the United States and Europe. Second, China could not indefinitely dispense with the currency represented by these shipments of sycee and dollars that have taken place. The reflex influence of the operations referred to must ultimately be felt by the future trade in China, inasmuch as the replacement of the exported currency, which may amount to one-quarter of the world's production for 1 year or even more, will influence considerably the price of silver and China exchange rates in sympathy. The shorter the period during which such replacement takes place, the more powerful the leverage will be upon the price of silver.

It is not surprising that the Indian Mint has figured as an extremely important buyer, for there has been not only external demand for silver rupees incidental to the war, but Indian crops have commanded unusually high prices. The Indian peasants, therefore, required correspondingly large payments in a unit commensurate to their daily needs.

Concerning the future of silver, present world conditions being unprecedented, and the course of events touching finance so uncertain, any forecast of future movements of the price would be guesswork. However, two factors can reasonably be anticipated to be an influence during the war; namely: a more or less persistent demand for silver currency as a consequence of the locking up of gold and other causes, and a degree of stringency of supplies, owing to the great drain made on them during the past year.

AVERAGE PRICE OF SILVER IN NEW YORK, 1865–1916
(In cents per fine ounce)

Year.		Year.		Year.		Year.		Year.	
1865.......	$1.337	1875...	$1.24	1885...	$1.07	1895...	$0.65	1905...	$0.61
1866.......	1.339	1876...	1.16	1886...	0.99	1896...	0.68	1906...	0.67
1867.......	1.33	1877...	1.20	1887...	0.98	1897...	0.60	....	....
1868.......	1.326	1878...	1.15	1888...	0.94	1898...	0.59	....	....
1869.......	1.325	1879...	1.12	1889...	0.94	1899...	0.60	....	....
1870.......	1.328	1880...	1.15	1890...	1.05	1900...	0.62	....	....
1871.......	1.325	1881...	1.13	1891...	0.99	1901...	0.60	....	....
1872.......	1.322	1882...	1.14	1892...	0.87	1902...	0.53	....	....
1873.......	1.297	1883...	1.11	1893...	0.78	1903...	0.54	....	....
1874.......	1.278	1884...	1.11	1894...	0.63	1904...	0.58	....	......

Year.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
1907....	68.673	68.835	67.579	65.462	65.981	67.090	68.144	68.745	67.792	62.435	58.677	54.565	65.327
1908....	55.678	56.000	55.365	54.505	52.795	53.663	53.115	51.683	51.720	51.431	49.647	48.769	52.864
1909....	51.750	51.472	50.468	51.428	52.905	52.538	51.043	51.125	51.440	50.923	50.703	52.226	51.502
1910....	52.375	51.534	51.454	53.221	53.870	53.462	54.150	52.912	53.295	55.490	55.635	54.428	53.486
1911....	53.795	52.222	52.745	53.325	53.308	53.043	52.630	52.171	52.440	53.340	55.719	54.905	53.304
1912....	56.260	59.043	58.375	59.207	60.880	61.290	60.654	61.606	63.078	63.471	62.792	63.365	60.835
1913....	62.938	61.646	57.870	59.490	60.361	58.990	58.721	59.293	60.640	60.793	58.995	57.760	57.791
1914....	57.572	57.502	58.067	58.519	58.175	56.471	54.678	54.344	53.290	50.654	49.082	49.375	54.811
1915....	48.855	48.477	50.241	50.250	49.915	49.034	47.519	47.163	48.680	49.385	51.714	54.971	49.684
1916....	56.775	56.755	57.935	64.415	74.269	65.024	62.940	66.083	68.515	67.855	71.604	75.765	65.661

PRODUCTION OF GOLD IN THE UNITED STATES (*a*)

States.	1913.		1914.		1915.		1916.	
	Fine Ounces.	Value. (*b*)	Fine Ounces.	Value. (*b*)	Fine Ounces.	Value. (*b*)	Fine Ounces.	Value. (*b*)
Alabama	443	$9,200	495	$12,300	247	$5,100	339	$7,000
Alaska	735,364	15,201,300	800,471	16,547,200	808,346	16,710,000	785,721	16,242,300
Arizona	198,406	4,101,400	221,020	4,568,900	220,392	4,555,900	211,805	4,378,400
California	979,174	20,241,300	1,028,061	21,251,900	1,090,731	22,547,400	1,069,586	22,110,300
Colorado	876,057	18,109,700	962,779	19,902,400	1,089,928	22,530,800	919,565	19,009,100
Georgia	645	13,300	813	16,800	1,684	34,800	977	20,200
Idaho	60,193	1,244,300	57,431	1,187,200	56,628	1,170,600	47,006	971,700
Montana	160,647	3,320,900	200,446	4,143,600	240,825	4,978,300	221,335	4,575,400
Nevada	579,408	11,977,400	558,064	11,536,200	574,874	11,883,700	407,714	8,428,200
New Mexico	43,149	892,000	58,974	1,219,100	70,632	1,460,100	67,870	1,403,000
North Carolina	5,574	115,200	6,303	130,300	8,258	170,700	1,437	29,700
Oregon	71,495	1,477,900	76,887	1,589,400	90,321	1,867,100	91,990	1,901,600
South Carolina	198	4,100	155	3,200	174	3,600	15	300
South Dakota	348,988	7,214,200	354,782	7,334,000	358,145	7,403,500	363,403	7,512,200
Tennessee	371	7,700	309	6,400	329	6,800	290	6,000
Texas	11	200	426	8,800	87	1,800	24	500
Utah	172,711	3,570,300	163,362	3,377,000	189,045	3,907,900	173,831	3,593,400
Virginia	11	200	15	300	24	500	63	1,300
Washington	31,806	657,500	28,435	587,800	22,330	461,600	23,791	491,800
Wyoming	847	17,500	324	6,700	672	13,900	4,054	83,800
Other States	32	700	10	200	....	....	....	....
Total	4,265,530	$88,176,300	4,519,662	$94,429,700	4,825,311	$99,748,000	4,390,816	$90,766,200
Porto Rico	50	1,100	135	2,800	34	700	29	600
Philippine Islands	34,204	707,000	53,179	1,099,300	63,898	1,320,900	74,962	1,549,600
Total	4,299,784	$88,884,400	4,572,976	$94,531,800	4,887,604	$101,035,700	4,465,807	$92,316,400

(*a*) The statistics in this table are reported by the Director of the Mint, those for 1916 being the preliminary figures (subject to revision). (*b*) At $20.67 per oz.

SILVER PRODUCTION OF THE UNITED STATES (*a*)

	1915.		1916.	
	Fine Ounces.	Value. (*b*)	Fine Ounces.	Value. (*c*)
Alabama	....	....	....	....
Alaska	1,054,634	$526,100	1,426,300	$938,500
Arizona	5,665,672	2,826,500	6,711,800	4,416,300
California	1,689,924	843,100	1,937,300	1,274,700
Colorado	7,199,745	3,591,900	7,771,500	5,113,600
Georgia	141	100	100	70
Idaho	13,042,466	6,506,800	10,504,100	6,911,900
Illinois	3,892	1,900	....	....
Maryland	....	....	....	....
Michigan	581,874	290,300	572,600	374,800
Missouri	55,534	27,700	52,000	34,200
Montana	14,423,173	7,195,600	14,751,000	9,706,200
Nevada	14,453,085	7,210,500	12,784,600	8,412,300
New Hampshire	....	....	300	200
New Mexico	2,337,064	1,165,900	2,000,000	1,316,000
North Carolina	1,496	700	400	270
Oklahoma	....	....	400	270
Oregon	125,499	62,600	163,800	108,400
Philippine Islands	15,148	7,600	17,900	11,800
Porto Rico	....	....	500	330
South Dakota	197,569	98,600	212,800	141,000
Tennessee	99,171	49,500	103,400	68,100
Texas	724,580	361,500	689,500	453,700
Utah	13,073,471	6,522,200	12,965,700	8,531,500
Vermont	....	....	2,000	1,320
Virginia	150	100	4,900	3,300
Washington	213,877	106,700	206,200	135,680
Wyoming	2,910	1,400	4,700	3,100
Total	74,961,075	$37,397,300	72,883,800	$47,957,540

(*a*) Figures of the Bureau of the Mint and the U. S. Geological Survey, those for 1916 being a preliminary estimate. (*b*) At $0.499 per oz. (*c*) At $0.658 per oz.

SILVER PRODUCTION OF THE WORLD

Country.	1914.			1915.			1916.		
	Oz. Fine.	Kilo-grams.	Value (*d*).	Oz. Fine.	Kilo-grams.	Value.	Oz. Fine.	Kilo-grams.	Value.
North America:									
United States	(*b*)72,455,100	2,253,657	$40,067,700	74,961,075	2,331,604	$38,898,801	72,883,800	2,266,905	$47,957,540
Canada	(*a*)28,449,821	884,909	15,593,630	26,625,960	828,147	13,228,842	25,669,172	798,888	16,854,635
Mexico	(*b*)27,546,752	856,820	15,236,659	39,570,151	1,230,798	20,533,743	...	...	...
Central America	(*b*)2,754,868	85,688	1,523,773	2,920,496	90,838	1,515,504	...	...	...
South America:									
Argentina	(*c*)35,271	1,097	19,500	...	...	...	...	...	...
Bolivia and Chile	(*b*)789,685	24,563	436,791	3,870,065	120,375	2,008,244	...	...	...
Columbia	(*b*)351,311	10,927	194,300	...	...	...	...	...	...
Ecuador	(*b*)16,726	520	9,251	24,655	767	12,794	...	...	...
Peru	(*b*)9,214,190	286,600	5,096,553	9,419,950	293,000	4,888,200	...	...	...
Europe:									
Austria Hungary	(*b*)1,572,746	48,919	869,917	...	...	...	...	...	...
France	(*c*)520,766	16,198	288,000	...	...	...	...	...	...
Germany	(*c*)4,984,677	155,044	2,734,500	...	...	...	...	...	...
Greece	(*b*)591,464	18,397	327,150	(*a*)391,200	12,168	203,033	...	...	...
Italy	(*a*)559,291	17,981	309,288	493,888	15,362	256,328	...	...	...
Norway	(*b*)440,917	13,714	243,880	...	...	...	...	...	...
Portugal	(*b*)205,822	6,402	113,800	2,058	64	1,068	...	...	...
Russia	(*c*)498,711	15,512	275,787	...	...	...	...	...	...
Spain	(*b*)4,231,815	131,527	2,340,200	4,565,396	142,003	2,369,075	...	...	...
Sweden	(*b*)33,511	1,042	18,536	24,241	754	12,579	...	...	...
Turkey	(*b*)1,509,133	46,940	834,600	...	...	...	...	...	...
United Kingdom	(*b*)135,458	4,213	74,925	96,450	3,000	50,050	...	...	...
Asia:									
British India	(*b*)236,446	7,354	130,900	284,875	8,861	147,827	...	...	...
Dutch Indies	(*c*)465,980	14,498	257,700	...	...	...	...	...	...
Formosa	(*c*)51,763	1,610	28,600	46,976	1,461	24,377	...	...	...
Japan	(*b*)4,836,228	150,427	2,675,014	5,079,552	157,995	2,635,881	5,536,037	172,194	3,642,712
Africa	(*b*)1,058,550	32,925	585,505	1,188,039	36,954	616,497	...	...	...
Australasia	(*b*)3,573,077	111,136	1,976,341	4,295,755	133,616	2,229,153	...	...	...
Other countries	(*b*)107,330	3,339	55,665	62,685	1,949	32,529	...	...	...
Total	171,429,432	5,201,959	92,318,465	179,753,978	5,591,104	93,292,315	177,000,000	5,517,000	116,466,000

(*a*) Official statistics of the country. (*b*) United States Mint Report. (*c*) Estimated. (*d*) The value of silver unless specifically reported in the official statistics of the country is taken as $0.553 in 1914, $0.519 in 1915 and $0.658 in 1916. (London quotations.)

Gold and Silver Mining in the United States

The following pages cover the important events during the past year, also the prospects of additions to the precious-metal output from several new districts. In the extraction of $92,000,000 of gold and 72,883,000 oz. of silver there is treated approximately 11,000,000 tons of gold ore, and 1,400,000 tons of silver ore during the year. Where most of this is mined is told in this section of the chapter.

Alaska.—Preliminary estimates by Alfred H. Brooks of the U. S. Geological Survey place the gold output in 1916 at $17,050,000, compared with $16,700,000 in 1915. This makes $277,900,000 to date. The data in hand indicate that the value of the placer gold output in 1916 was $10,640,000; in 1915 it was $10,480,000. About 640 placer mines were operated in 1916, employing some 4600 men. All the older districts appear to have held up or increased their output compared with the previous year, except Fairbanks. The increased output is, however, to be credited chiefly to the new camps of Marshall and Tolovana. (A preliminary report on the Tolovana district, by Alfred H. Brooks, appeared in *Bulletin* 642-G of the U. S. Geological Survey. Placer production so far has been confined to Livengood creek. In 1915 the output from 10 mines was $80,000. The deposits are in four classes, deep, bench, and creek gravels, and slide material. There is abundant timber available, but hardly enough water for sluicing.) Thirty-six gold dredges were operated in Alaska in 1916, one more than in 1915—29 in Seward Peninsula, three in the Iditarod, and one each in the Ruby, Fairbanks, Circle, and Yentna districts. Of these 36 dredges four were installed in 1916. It is estimated that these dredges produced between $2,000,000

Fig. 1.—Alaska.

and $2,200,000 worth of gold. If the final figures bear out this estimate, it indicates a lower recovery per dredge than in the previous year. In 1915 the 35 dredges recovered $2,330,000 worth of gold. Prospecting before dredging on Seward Peninsula is discussed[1] by Corey C. Brayton, who starts with the churn-drill used in 1902. The Keystone drill followed satisfactorily, but this is an expensive machine for the average man or syndicate. The driving of pipes into the gravel was a method in vogue for some time. The light-weight power-rig finally was adopted for testing ground 15 or 20 ft. deep. It is called pipe-driving or drilling. The

[1] *Min. Sci. Press*, **112**, 627 (1916).

method is accurate, quick, and cheap. Many mistakes were made in dredge construction in this region, of which Nome is the port. The loose gravel is shallow, and the flume type of dredge was evolved for such conditions. The screen type has its field also. Men inexperienced in dredging elsewhere developed the power-drill and flume-dredge. The same writer detailed[1] dredging for gold on Seward Peninsula during the season of 1916. Forty-two boats operated, being of the flume and screen types. Bucket-capacities are from 2 to 8½ cu. ft.; but there are few over 5 cu. ft. Most of the dredges are near Nome, or east and northeast of that place.

Near Juneau interest centered on the Alaska Gastineau company's results. Returns varied considerably from 114,183 tons of $1.42 ore in January to 165,930 tons of 94-ct. ore in April. December yielded 196,495 tons averaging $1.22. The year's output was 1,888,869 tons averaging $1.23 per ton. The recovery was 81 per cent., and cost 71 cts. per ton. The profit was $560,000 less $180,000 for bond interest. In 1915 the 1,115,294 tons of ore assayed $1.15 per ton. Shares fell to around $10, a big drop from their previous figure of $42. However, conditions are reported to be better, which is to be hoped. The Alaska Juneau company continued its construction work, and by March, 1917, the new mill is expected to be treating ore. (The first unit started in April, 1917.)

About 25 gold-lode mines were operated in 1916, compared with 28 in 1915. The value of the output increased from $6,069,000 in 1915 to $6,200,000 in 1916. Southeastern Alaska, especially the Juneau district, is still the only center of large quartz-mining developments in the Territory. Next in importance is the Willow Creek lode district. There was also considerable gold-lode mining on Prince William Sound, but a decided falling off of this industry in the Fairbanks district. Lode-mine owners of Fairbanks are awaiting the cheapening of operating costs, especially of fuel, which will be brought about by the Government railroad. The metal output of the Territory was $50,900,000, an increase of 54 per cent.

Events on Douglas Island, opposite Juneau, were watched with as much interest as those on the mainland. The group on the island consists of the Alaska Treadwell, Alaska Mexican, and Alaska United mines, which, to the middle of 1916 had produced a total of $62,797,460 from 26,464,047 tons of ore, an average of $2.37 per ton. The cost was $1.42, and dividends $0.81 per ton. For years the three companies have been under the one management, and as development and treatment operations became more interlocked, a consolidation seemed necessary. During August an 85-page report, that of the Consolidation Committee—

[1] *Min. Sci. Press*, **114**, 43 (1917).

H. C. Perkins, Hennen Jennings, and F. W. Bradley—was issued to shareholders. This covered management of the mines, mills, ore reserves, annual reports, geology, and valuations for consolidation. Of the 14,000,000 tons of ore in reserve, only about 8,000,000 tons may be safely extracted. It is impossible to estimate the recoverable ore under present operating conditions, as there is danger from further caving. The equitable basis for consolidation was 54 per cent. for the Treadwell, 34 per cent. for the United, and 12 per cent. for the Mexican, of the total. Late in December a 126-page report was issued to shareholders. This contained a financial program with the end of 1919, and a technical report on surface subsidence and water conditions at the group of mines, by L. Wernecke, the geologist. It may be said that owing to evidence of subsidences at the end of July near the Treadwell 700-ft. mine boundary on the shore of Gastineau channel, it was deemed advisable to stop heavy drawing of broken ore and caved-pillar ore from upper levels in the Treadwell. Accordingly on Aug. 1, 390 stamps were stopped crushing. Exploration is now under way to prove the mines at depth, 2300 ft. and lower. The shutting down of these stamps—390 out of 960—meant a considerable reduction in gold output for 1916. It is proposed to centralize operations on the surface, and eventually costs will be lowered. The Treadwell group in 1916 yielded as follows: 1,472,770 tons for $2,469,950, of which $381,470 was profit, and $304,060 was paid in dividends. Comparative for 1915 were: 1,652,300 tons, $3,250,720, $1,302,650, and $952,280, respectively. (During April, 1917, a subsidence let in the water of Gastineau channel, flooding 3 mines, whose future is now problematical. The Ready Bullion mine is intact.)

Concerning the mines in the Juneau district an editorial in *The Mining Magazine*, London, of March, 1916, reviewed the situation of the Alaska Treadwell, Alaska Mexican, Alaska United, Alaska Gold Mines, Alaska Juneau, and Ebner properties, who controls them, and their prospects. The Treadwell companies were pioneers in wholesale mining of low-grade gold ore at low cost.

Arizona.—The total value of all metals produced in this State last year was $203,000,000, an increase of $113,000,000, gold increasing from $4,166,025 in 1915 to approximately $4,427,000 in 1916, an increase of over 6 per cent. The production of gold from copper ores in most counties was naturally greater than in 1915, but there was a marked decrease in the output of bullion from amalgamation and cyanide mills, particularly in Mohave and Maricopa Counties. Several new gold mines were added to the list during the year, especially in the Oatman field, Mohave County; but the production was not sufficient to off-set the decline in the output of the older properties. A new 200-ton mill was completed for the United Eastern property, and considerable ore was opened at the Big Jim and Gold Ore mines.

The production of silver from the mines increased from 5,649,020 to a record output of 6,823,000 oz. in 1916. As the market price was much higher, the value increased from $2,864,053, to nearly $4,490,000, an increase of nearly 57 per cent. in value. There was no great change in the production from the Commonwealth property, which is principally a silver producer, so the increase is to be credited largely to the remarkable output of copper ore.

In *Bulletin* 620-H of the U. S. Geological Survey the Kofa mining district of Yuma County, Arizona, was described by E. L. Jones, Jr. The mountains are isolated in the center of the county. The gold deposits consist of brecciated zones and veins in andesite. At the King of Arizona and North Star mines the outputs were $3,500,000 and $1,100,000, respectively. They are now closed, as the ore became too low-grade.

In *Bulletin* 620-C of the U. S. Geological Survey, E. L. Jones, Jr., described the gold deposits near Quartzite, Ariz. Placer mining here dates back to 1862. Until 1868 the annual output was $1,000,000; since then it has been very small.

Early in 1916 there were 100 companies in the Oatman district either developing properties or hurrying equipment for extensive development; at the end of the year there were 50 companies still working on a fairly large scale, the Tom Reed and United Eastern producing gold, while two or three others promised well. Under the title[1] of "Oatman, Arizona—A Prohibition Camp," Frank H. Probert mixes geology and the human side of Oatman. The veins outcrop, either as prominent silicified ribs in the softer andesites or as shallow depressions in the quartz-porphyry or rhyolite, all showing more or less brecciated rock fragments cemented by calcite or quartz. The ore occurs as a series of lenses pinching vertically and horizontally within the vein-filling. Owing to the re-opening of fractures, oxidation and leaching are advanced. Gold is seldom found near the surface in payable quantity. Before cross-cutting to the vein or driving along it is attempted, shafts must be sunk from 300 to 500 ft. A careful geological study is necessary to prevent useless expense in exploration, and this is being done by several companies. Mr. Probert considered that a study was important of: (1) the true nature of the younger andesite; (2) the influence of later volcanic disturbances on vein-structure; (3) the relationship between value of ore and replacement of calc-spar by secondary quartz; (4) the influence of oxidation on the vertical distribution of ore; and (5) the inference that can be drawn as to the nature of deep-seated ore from the character of that now developed. The subject

[1] *Min. Sci. Press*, **112**, 17 (1916).

of oxidation is important. None of the mines is wet, and ground-water level has not been established in any workings on the vein-system.

The Tom Reed-Gold Road mining district (Oatman) was discussed[1] by J. D. Sperr of the Tom Reed company. The region is characterized by lack of sedimentary rocks. Profound fissuring resulted in veins not yet bottomed by deepest workings. In January, Oatman experienced a big boom, 100 companies being incorporated, 40 of which were operating, 10 having good milling ore, and three having large producing mines of proved merit. Leroy A. Palmer also dealt with the district,[2] covering underground methods, treatment, surface equipment, etc. It is probable that Oatman will be a large low-grade center.

John B. Platts[3] considers that no two writers agree on the geology of Oatman. After giving his views on the basal formations he says that the most important ore-producing veins, such as those in the Tom Reed, United Eastern, and Big Jim mines, are in a complicated series of fissures. Some of these strike N. 45° W., others N. 60° W. Many intersections are produced and large ore-bodies are found near many of the crossings. The original vein-filling, calcite, of low value, was replaced by quartz and adularia. The gold occurs principally in hematite in the quartz. Save for oxidation of the pyrite there is no evidence of the action of surface water on the ore; therefore, Mr. Platts believes that the ore is essentially a primary deposit formed by hot-ascending water.

Current events, geology, developments, and possibilities in the Oatman district were described by W. A. Scott[4] and Etienne A. Ritter[5] in an interesting manner, though nothing new was elicited by their investigation of the field.

California.—Metal production of the western state in 1916 totaled $44,384,000, an increase of 38 per cent., according to Charles G. Yale. The mine figures for gold in 1915 were $22,442,296; estimates for 1916 indicate an output of $22,939,000, an increase of $497,000, or 6 per cent. The gold yield is the largest in 33 years and, with one exception, the largest in 52 years. The gold increase for 1916 is the more notable because a number of the most productive mines in the Mother Lode region of the State, in Amador County, were closed by labor strikes for nearly 50 days, and the loss entailed by the stoppage of the mills was more than $500,000. There are over 600 productive metal mines in the State, about evenly divided in number between deep and placer properties. From the deep mines the annual output of ore now exceeds 3,000,000 tons. In value of all metals produced, Shasta is the leading county; and in value of gold

[1] *Eng. Min. Jour.*, **101**, 1 (1916).
[2] *Loc. cit.*, p. 895.
[3] *Min. Sci. Press*, **112**, 627 (1916).
[4] *Loc. cit.*, p. 814.
[5] *Min. Eng. World*, **44**, 1033 and 645 (1916).

output Amador, Nevada, Yuba, Sacramento, Butte, Calaveras, Shasta, and Tuolumne, are the leading counties in the order named. The placer mines of the State continue to produce about 38 per cent. of the annual gold yield; the dredges account for 35 per cent. of the total gold, or 90 per cent. of the placer gold yield. There are now 59 dredges at work in the different fields, the most productive of which are in Yuba, Sacramento, and Butte Counties. The yield is declining in the Oroville field and fewer machines are at work, some of them on old dredge tailing. Some new dredges were built in the Folsom field in 1916 and others reconstructed. The Yuba River or Marysville field is now the most important dredge area in the State. Four large new dredges were constructed in this field in 1916, and the yardage handled each year is increasing. One machine recently launched has 18-cu. ft. buckets, and will handle 350,000 yd. monthly, digging to a depth below water level of 87 ft. In this field so far in 1916 the yield of the gravel has been 12.87 cts. per cu. yd., at a working cost of 3.7 cts. Dredging is going on at the rate of 150,000,000 cu. yd. per year. New machines have been installed in 1916 at several places in what are known as the outside districts, but these are generally of smaller capacity than those in use in the larger fields.

The silver output from the mines in 1916 is estimated at 2,186,500 oz., valued at $1,438,700, an increase compared with 1915 of 508,000 oz. in quantity, and of $588,000, or 69 per cent., in value. The silver is derived mainly from the smelting of copper, lead, and zinc ores, although some silver is recovered also in gold-mining operations.

One of the most interesting operations during the year was the re-opening of the old Eureka mine at Sutter Creek, work that was started in March of 1916. At the end of the year the shaft had been unwatered to a depth of 1300 ft. Apart from slight caving little trouble was experienced in this work, and many of the timbers, under water for 30 years, are in splendid condition. A large electric hoist will soon be erected, and other modern equipment installed for continuous work. The owners have great faith in the future, and are to be commended.

The re-opening of old mines in California was a feature of the year, and T. A. Rickard[1] gave some past history when he visited the Mother Lode in June. Early work at the Old Eureka is described, with yields and costs, and the names of people connected prominently in those days. Miners were paid $3 per shift in 1869, as at present. The average yield of ore along the Mother Lode was $20.34 per ton 47 years ago, now it is $5; but the recovery has improved from 61 to 90 per cent. Although the full length of the Lode is 125 miles, it is productive for 71 miles of this distance, through Eldorado, Amador, Calaveras, Tuolumne, and Mariposa

[1] *Min. Sci. Press*, **112**, 935, and **113**, 236 (1916).

Counties. From over 1,500,000 tons the yield, by simple treatment, is $4.17 per ton. Metallurgy is vastly different from what it was in '69, and is still the object of improvements.

An instance of the possibilities in re-opening old mines is the Plymouth Consolidated at Plymouth. In 27 months it has yielded $1,500,000 from 270,000 tons of ore. Of this $460,000 was clear profit. The main shaft is 2450 ft. deep, and is to be sunk 300 ft. lower. Ore reserves are estimated at 180,000 tons. An electric hoist of 5000-ft. capacity has been installed. The man responsible for the introduction of capital for resumption at this and other mines is W. J. Loring. He is now re-opening the Hardenburg mine near Jackson, and has put the Dutch-Sweeney-App group at Sonora, Tuolumne County, on a productive basis. Oil flotation is part of the process at this mine. The Harvard mine is also under option to the same firm.

Dredging in California employs 64 boats of from 5- to 18-cu. ft. capacity. Of late there has been a good deal of prospecting for suitable ground, and dredges having completed digging in one part are dismantled and moved to another. On the Yuba there are 15 at work. One is busy in Calaveras County, with two being re-built, and two are digging on the Mokelumne River. At Oroville there are now only eight boats. An interesting departure is the re-treatment of the gravel tailing-piles by the Natomas company, so far said to be profitable. There is at least 25 sq. miles of this material for re-handling. In Trinity County there are two dredges, with two more under construction. At Natoma there are 11 boats digging. Owing to a decline in operations the Natomas company of California showed a profit of $588,789 for the 7 months ended July 31, 1916, while in the whole of 1915 the profit was $1,570,799. Satisfactory tests were made in the grinding and saving of gold in the heavy sand caught. The new boat near Redding is said to be paying well; another is being constructed. There seems to be a fair area of ground available in this district. On the Yuba River there was a good deal of dredging activity, also prospecting new areas. In December the Yuba Consolidated launched its largest boat, No. 16. Its buckets are of 18-cu. ft. capacity, and digging to a depth of 84 ft., the monthly yardage will be 350,000. The dredge weighs 2700 tons complete, and cost $500,000. During the year ended Feb. 29, 1916, this company treated 17,750,000 cu. yd. of gravel, yielding 12.02 cts. per yd. The cost was 4.27 cts. per yd. In the 5 months ended July 31, 1916, the gravel yielded 12.87 cts., while costs were lowered to 3.7 cts. The present rate of profit is $1,800,000 per year.

Hydraulicking continued at several points in Trinity County. The old Lagrange mine has operated at a loss lately, according to a report of the Consolidated Gold Fields of South Africa, which controls the property. Last season there was sluiced 2,000,000 cu. yd., yielding 2 cts. per yd., but the cost was 4 cts. per yd. By shortening and altering the grade of the sluice-boxes it is estimated that 4,000,000 cu. yd. could be moved, and the cost reduced by 50 per cent. or more. Some hydraulicking was done in Nevada County. On Slate creek, near Oroville, a concrete restraining dam was constructed to hold gravel and permission having been received, sluicing is to commence in 1917.

The California State Mining Bureau is preparing a new general report on the mineral resources of the State, and instead of waiting until the entire area is covered, advance chapters are being issued, by groups of adjacent counties, as soon as completed. These chapters are well illustrated with photos and drawings. The following chapters were published: Amador, Calaveras, and Tuolumne Counties (Mother Lode); Colusa, Glenn, Lake, Marin, Napa, Solano, Sonoma, and Yolo; Del Norte, Mendocino, and Humboldt; Fresno, Kern, Kings, Madera, Mariposa, Merced, San Joaquin, and Stanislaus; and Shasta, Siskiyou, and Trinity. The first- and last-mentioned chapters include some important gold-mining districts.

Colorado.—Owing to the incentive given by high prices of base metals the precious metals received rather less attention during 1916. This is shown by the decreased output of gold, which fell from $22,414,944 in 1915 to $18,940,000 in 1916. The silver yield increased from 7,027,972 to 7,620,000 oz., due to greater shipments of copper, lead, and zinc ores. Cripple Creek produced $11,800,000 in gold, a drop of $1,883,000, in spite of vigorous development at depth, following the lowering of the water level by extension of the Roosevelt drainage tunnel. All the large mills, save Strattons, worked steadily, but the small plants were not regularly operated. Leadville and district produced gold worth $1,760,000 and 3,030,000 oz. of silver, a decrease of $500,000 in the former but an increase of 500,000 oz. of the latter. The extensive drainage schemes under way will increase the silver output in 1917. The San Juan region reported a decrease of $834,000 in gold and 178,000 oz. of silver. Ouray County was mostly responsible for this, in which is the Camp Bird mine, where a 10,700-ft. tunnel is being driven, of which 3600 ft. has been accomplished. "Camp Bird Going Deeper" is the title of an editorial,[1] in which the driving of a 10,700-ft. adit to explore the ground 400 ft. below the lowest workings, is discussed from a geological standpoint. This work should be completed during 1917. The Camp Bird has proved to be one of those rare mines that has been continuously disappointing—but always on the right side. The mill is now closed pending the completion of the new explora-

[1] *Min. Mag.*, March, 1916.

tion. Boulder, Clear Creek, and Gilpin Counties had lower yields by $250,000 of gold and 40,000 oz. of silver. In Summit County, where four dredges are working at Breckenridge, the gold yield fell $20,000, while the silver gained 36,000 oz. The tonnage of ore treated from Cripple Creek mines was 975,270, a decrease of 3 per cent. Dividends totaled $3,944,321, compared with $6,493,225. The Vindicator company's new 350-ton flotation mill is now in operation. By April, 1917, the Portland will have its new 3000-ton sampler, and the 1500-ton Independence flotation-cyanide mill at work. Extension of the Roosevelt drainage tunnel at Cripple Creek is being continued, the ultimate value of which is well known. Operations at the tunnel and at some of the large mines were described[1] by W. A. Scott. The tunnel—7 by 9 ft.—is in over 23,000 ft. from the portal. The destination is the Vindicator's Golden Cycle mine, over 5000 ft. from the face. The flow of water is subject to considerable variation, the quantity being in September 10,300 gal. per min. Rock is now hoisted through the Elkton shaft. General conditions at the Portland, Cresson, Vindicator, Isabella, Stratton Estate, Granite groups, Mary McKinney, and Gold Sovereign mines, underground and at mills, were briefly described.

Idaho.—Estimates by C. N. Gerry of the U. S. Geological Survey show that the mine production of gold decreased from $1,179,731 in 1915 to $1,098,000 in 1916, a decrease of 7 per cent. Part of the decrease was due to the smaller placer output from dredging. The gold output from copper ore, lead ore, and lead-zinc ore, however, was increased. The most important dredge operations were those of the Boston-Idaho, Boise County, and the Kirtley Creek and Bohannon Bar, Lemhi County. Work progressed at deep gold mines at Atlanta, Elmore County, and in Custer County. Mills were active at the Nellie mine at Horseshoe Bend and the Lucky Boy mine, Boise County.

The mine output of silver increased from 11,769,128 to approximately 12,300,000 oz. in 1916. As the price of silver was much above that of 1915, the value of the output increased from $5,966,948 to $8,225,000, or 38 per cent. There probably would have been a greater increase in the silver production from lead and lead-zinc ores had it not been for the peculiar smelting conditions during the year, as the Northport smelter, which received the Hercules ore, was being completed, and the Bunker Hill & Sullivan at Kellogg was beginning smelter construction. Each of the following mines produced more than 1,000,000, oz. of silver: Hercules, Bunker Hill, Morning, Greenhill-Cleveland, Caledonia and Hecla.

Lode mining in the Quartzburg and Grimes Pass porphyry belt in

[1] *Min. Eng. World*, **45**, 613 (1916).

Boise Basin, Idaho, was described in *Bulletin* 640-E of the U. S. Geological Survey by E. L. Jones, Jr. Quartz mining commenced soon after the placers were found. In 1867 there were 10 mills treating free-milling ores. From 1863 to 1914 the gold output is estimated at $53,096,995. Large dredges are now working the creek-bed gravels, in 1912, 1913, and 1914 the yield being over $500,000 per year. The future of the region will depend largely on the adoption of suitable treatment for the ores, which are becoming increasingly base. A process is reported to have been devised for their treatment.

Gold from the Snake River alluvial flats in Idaho is so fine that it takes from 1000 to 2000 colors to equal 1 ct., according to J. M. Hill's *Bulletin* 620-L, published by the U. S. Geological Survey. Along the course of the river can be seen the wrecks of numerous attempts to save the gold, including dredges. Countless process machines were tried, even cyaniding. The best appliance is the burlap-table, the burlap catching the fine gold and heavy sand. The gold and concentrate is ground and amalgamated in the ordinary way.

Montana.—Victor C. Heikes, of the U. S. Geological Survey estimates that the mine output of gold was valued at $4,550,486, a decrease of nearly 9 per cent. from $5,004,186 in 1915. Much gold came from the Scratch Gravel district and the Piegan-Gloster mine, in Lewis & Clark County, and from the Ruby Gulch and August, in Phillips County. The production of gold from ores milled was in several places less than in 1915, and even the gold output from siliceous ores smelted seems to be declining. The placer-gold output decreased, especially that from dredge operations, though sluicing was begun below Troy, in Lincoln County.

The mine output of silver in Montana increased from 14,378,437 to 16,494,366 oz. The value, on account of better prices, increased from $7,289,868 to $10,853,291, or nearly 50 per cent. Most of this output came from ores and concentrates smelted, especially copper material (Anaconda, 10,000,000 oz.), in which there was a great increase, but a considerable quantity also came from the lead and zinc concentrate (Butte & Superior, over 300,000 oz. monthly) mined at Butte, of which there was a larger production. Work was resumed at the Ophir mine by the Butte-Detroit Copper & Zinc Co. and the mill was remodeled. The total metal production of the State was $145,000,000, an increase of 76 per cent.

Of late there has not been much of note from the gold and silver region contiguous to Helena, Mont., although genuine development is being done. L. S. Ropes deals[1] with activities in the Marysville district. Save at two properties, all veins have been opened by tunnels at from

[1] *Min. Eng. World*, **44**, 819 (1916).

400 to 600 ft. below the surface; development therefore is cheap. Mills may be erected near the portals of the tunnels. Electric power is available, and railroad service is right at hand. Generally the possibilities are favorable.

The Philipsburg quadrangle of 827 sq. miles, investigated by the U. S. Geological Survey, was described in a folio published in March. The geologists were W. H. Emmons and F. C. Calkins. Several important metalliferous mining districts are in this area, especially the silver centers of Flint Creek and Philipsburg. Ten miles away is Cable, a gold district.

O. W. Freeman wrote[1] on gold mining in the Judith Mountains, which are in central Montana. The valuable ore-bodies are replacement deposits of gold in limestone, near the contact with intrusive laccoliths or sheets. The best mines are near Maiden, the largest being the Spotted Horse, which yields $12,000 monthly. Others are the McGinness, Cumberland, War Eagle, Whiskey Gulch, and New Year. Careful prospecting and development should disclose large bodies of low-grade cheaply-mined gold ore.

The history and development of gold dredging in Montana was given in *Bulletin* 121 of the U. S. Bureau of Mines by Hennen Jennings. Since 1864 the evolution has been interesting, and many modern dredging apparatus were devised in Montana, especially by the Conrey Placer Co. This company operates at Alder Gulch, near Ruby, and since 1899 has dug 37,000,000 cu. yd., yielding 16 cts. per yd. The four boats now at work are motor-driven, and have 16-cu. ft. capacity buckets, handling 300,000 yd. per month each. One boat dug 411,000 yd. at a depth of 54 ft., at a cost of 2.66 cts. per yd. From Sept. 1, 1906, to July 31, 1915, a total of 31,379,890 cu. yd. was dug by four dredges, costing 6.96 cts. per yd. Winters are severe and the district is isolated. Complete machine shops are maintained for repairs.

Nevada.—The mine output of gold was valued at approximately $9,000,000 in 1916, a decrease of 22 per cent. from the output of 1915, which was $11,404,300. The gold output from copper ore was increased, but that from amalgamation and cyanide mills was less in many of the camps. The Pittsburg-Silver Peak mill, in Esmeralda County, was dismantled, and the Buckhorn, in Eureka County, was closed down. The former was an important producer in past years. The Goldfield Consolidated, which is the most important gold producer of the State, was treating approximately 30,000 tons of ore per month. The output, however, was considerably less than in former years. A large flotation plant was being added at this property. The Jumbo Extension doubled its ore output, shipping from 2000 to 3000 tons per month. Shipments were also made

[1] *Min. Sci. Press*, **112**, 863 (1916).

from the Atlanta, and flotation concentrate by the Nevada Metal Extraction Co. One of the most important additions to the gold and silver production was from the operations of a cyanide mill at the Elko Prince property at Midas. Operations at Seven Troughs, National, and Round Mountain were somewhat less than in the preceding year. From Searchlight, in Clark County, ore and precipitate were shipped, and at Rawhide, in Mineral County, the Nevada New Mines acquired the Black Eagle property and operated two mills. At Aurora there was also increase in gold output, according to V. C. Heikes of the U. S. Geological Survey.

The mine production of silver was 13,680,000 oz., which represents a decrease from 14,459,840 oz. in 1915. The value of this output, however, on account of the higher price of silver, increased from $7,331,139 to $9,000,000 or 23 per cent. The silver output comes chiefly from the Tonopah district, where there was a marked decrease. In 1915 the district produced 516,337 tons of ore, $2,228,983 in gold, and 10,171,374 oz. of silver; in 1916, approximately 448,000 tons of ore, $1,941,000 in gold, and 8,884,000 oz. of silver. The largest producers were the Tonopah Belmont, Tonopah Extension, Tonopah Mining, Jim Butler, West End, Montana Tonopah, Halifax Tonopah, and Tonopah Midway. The Rescue Eula and Cash Boy were new producers. At the Extension property 10 stamps were added to the mill equipment. In the Rochester district, of Humboldt County, there was an increase in both gold and silver production from mill operations at the Nevada Packard and the Rochester Mines Co., each treating 100 tons per day. The capacity of the plant of the Rochester Mines was doubled. Its output in 1916 was $400,000, an increase of $66,000. Since 1913 the total is $1,420,000. All costs at the Nevada Packard are $4.06 per ton. In the Comstock district, of Storey County, there was an increase of approximately 60 per cent. in the value of the gold and silver output. The production in 1915 was valued at $378,731. On Dec. 6 pumps started lowering water to the 2900-ft. level of the Comstock. A review of work done of the lode during 1916 is as follows:

(1) Opening of the Union shaft from the 2000- to the 2700-ft. level, making it the deepest vertical shaft operating in Nevada. This cuts out a long haul of nearly ½ mile through the drifts, and in addition greatly helps the ventilation. (2) Opening of the Union and Sierra Nevada winze from the 2500- to the 2700-ft. levels and the additional discovery that it is in good condition to 2900 ft. (3) The purchase and installation of pumps in the Mexican-Ophir winze, which have now commenced work, and will drain the North End mines to the 2900-ft. level, opening ground that has been flooded for over 30 years. (4) A great improvement

in ventilation which has made work at every point underground easier and cheaper. (5) The discovery of ore in Union, which has placed that mine in better financial condition than for 36 years. (6) The repairing of the Ophir shaft, the up-cast shaft of the North End Mines, thereby protecting them from any interruption of ventilation, and the enlarging of drifts that carry the air in many places. And (7) the commencement of work at the Combination shaft, which means active mining in the middle group, the center of the Comstock lode. This is all-important work, and should prove the existence or otherwise of silver at depth in the Comstock lode.

At Tonopah, mining continued to a depth of 1600 ft. with good results. In the suit of the Jim Butler *vs.* West End Consolidated, in which the trial court in May, 1915, decided in favor of the defendant, the Supreme Court of Nevada affirmed this judgment in July, 1916. The question was one of apex rights, in which two veins met at a point in the West End ground, dipping north into the McNamara and south into the Jim Butler. The West End followed the latter shoot into Jim Butler ground, hence the suit. A theory was propounded that the two limbs constituted an anticlinal arch. The Court considered that the crest of the anticlinal roll was the apex.

An unusual gas mixture—98.4 per cent. nitrogen and 0.52 per cent. oxygen—is found in the Tonopah-Goldfield district,[1] according to E. Steidle. This gas was given off from the "water-courses" and "vugs" in the ore-bodies. It collected in blind raises or in the tops of dead-end stopes. The gas is very dangerous to miners.

Affairs at Manhattan assumed a brighter aspect due to the consolidation of several properties and encouraging developments. The White Caps mine, at which a treatment plant involving roasting and cyanidation is being erected, was described[2] by J. L. Dynan. Recent discoveries of good ore at a depth of 950 ft. revived interest in the district. Below 150 ft. the ore is a sulphide, not easily treated like that in the oxidized zone. The Manhattan ore deposits occur in the sediments, and are of three types, as follows: (1) small gold-bearing veins, with a gangue consisting principally of quartz and calcite; (2) low-grade disseminations of free gold throughout the cleavage-planes of the schist; and (3) replacement deposits in the limestones. The White Caps ore-bodies belong to the third type, being a replacement of limestone by quartz, pyrite, arsenopyrite, and stibnite. Calcite, due to re-crystallization of limestone, is abundant. The value is 1.02 oz. gold and 0.02 oz. silver per ton. This mine affords an excellent example of the influence of structure upon ore deposition.

[1] *Min. Sci. Press*, **112**, 368 (1916).
[2] *Min. Sci. Press*, **113**, 884 (1916).

At Goldfield, underground developments during the year were of importance, as also were the advances in metallurgy. Discoveries of ore were made in virgin ground, these stimulating search outside the proved area. Several companies resumed work on a fairly large scale, others have good prospects of becoming producers. The Goldfield Consolidated, which produced $2,250,000 from 338,000 tons of ore, of which $460,000 was profit, a considerable decrease compared with that of 1915, remodeled its mill for flotation on gold-copper ore. After a short run this process was discontinued for several months until additional plant was installed, which would be early in 1917 (February). Returns from the Jumbo Extension fell off toward the end of the year (the total was 24,762 tons of $28.67 ore, giving a profit of $177,000). The management considered that the outlook was not bright, and is examining other properties with a view to purchase. Encouraging conditions were found at 1100 ft. in the Silver Pick, and exploration of the alaskite contact continues. The Florence Goldfield successfully operated a 200-ton flotation plant on its gold-copper ore for a while, but the ore became too low-grade, so treatment was suspended. Exploration by the Kewanas, Atlanta, Merger, Sandstorm-Kendall, and Jumbo Junior resulted in proving conditions that may improve during 1917. The need of local treatment of the gold-copper ore is shown when costs are compared. The Goldfield Consolidated reports a total of $4.54 per ton, including 4 cts. per ton for filter and 4 cts. for flotation royalties. It cost the Jumbo Extension $21.12 per ton to mine, ship to smelter, and treat its ore.

New Mexico.—Of the total value of all metals produced in 1916, $33,469,400, Charles W. Henderson of the U. S. Geological Survey estimates a decrease of $111,105 in gold and 205,531 oz. of silver.

The Mogollon district, Socorro County (reached at present from the railroad at Silver City, Grant County, 80 miles distant), continued to be the most productive district in New Mexico for gold and silver. There was a great deal of new development work in this district in 1916, but the yield decreased appreciably. The Socorro (Fanney) and the Mogollon (Ernestine, 7171 oz. gold and 371,350 oz. silver) mines and mills were operated. All the ore was milled in the district by concentration, sliming, and agitation, and percolation in cyanide solution, the bulk of the product being cyanide precipitate, the balance being high-grade gold-silver concentrate. The prospects for oil-flotation processes are good. Transport is being improved by motor-trucks and better roads. Hydro-electric power is to be developed. An aerial tram at the Pacific mine dispensed with burros, etc. All of these improvements tend to lower costs. The Elizabethtown district, Colfax County, from the Aztec mine alone, was also a large producer of metallic gold, gold bullion, and gold concentrate. The Cossak cyanide mill, in the Cochiti (Bland) district, Sandoval county, closed in December, 1915, was started up again in the spring of 1916 and contributed a considerable yield of silver-gold bullion. Gold bullion continued to be produced at the amalgamation mill on the North and South Homestake mines, at Whiteoaks, Lincoln County. The Lordsburg district, Grant County, which has been steadily increasing its shipments of siliceous gold- and silver-bearing copper ores, again greatly increased its tonnage shipped. The copper concentrate of the Chino Copper Co., contributed to the gold yield. The continued activity of the mines and matte smelter at San Pedro, Santa Fe County, also added an increased quantity of gold to the New Mexico yield. Shipments of copper ores from the Jarilla district, Otero County, carried some gold.

The Aztec gold mine at Baldy, N. M., was described by W. T. Lee in *Bulletin* 620-N of the U. S. Geological Survey. The mine was a famous producer 45 years ago. Litigation started in 1872. In 1867 placer mining was done on Willow Creek, yielding $2,250,000. A year later the source of this gold was found, the outcrop of the Aztec mine, and $1,000,000 was extracted in the first four years. The rich ore became exhausted. For over 40 years efforts were made to find other shoots. In 1909 J. T. Sparks explored the quartzite-slate contact, and in August, 1914, E. O. Deshayes came across a rich deposit. In 1915 the 10-stamp mill was crushing $107 ore. Most of the ore is in the underlying shale.

Oregon.—According to C. G. Yale the 1916 output of gold was $1,900,000, an increase of $38,000. No very productive new mines were opened. Baker County yields 90 per cent. of all this State's gold, where are the Cornucopia and Baker mines. Among the many placer mines in Oregon the Columbia Mines Co. in Josephine County is the most productive hydraulic property. Near Sumpter the Powder River Dredge Co. operates two boats. This is the largest gold placer property in the State. A new dredge was under construction in the John Day valley of Grant County. The silver output increased from 117,947 to 227,500 oz. This metal is contained in the gold and copper ores.

Mining operations in Western Oregon were described[1] by E. C. Morse, incidentally reviewing the State in brief. The mines in the Bohemia district paid dividends 15 years ago, but with depth the ores become too refractory for the known treatment methods. H. S. Reed, Jr., also gives[2] some notes on this district, where he was employed in 1900, including treatment tests and results.

South Dakota.—The production of gold in 1916 was $7,463,000, compared with $7,406,305 in 1915 and that of silver was 209,000 oz., compared

[1] *Min. Sci. Press*, **112**, 169 (1916).
[2] *Loc. cit.*, 366.

with 199,864 oz. in 1915. These are preliminary estimates reported by Charles W. Henderson, of the U. S. Geological Survey. The Homestake mine and amalgamation-cyanidation mills were operated continuously throughout the year with an increased output. All the other cyanide mills in Lawrence County were operated steadily, with the exception of the Bismarck. During part of the year the Deadwood-Standard cyanide mill was also operated on ore from the Slavonia property. A small production of placer gold was made in Custer, Lawrence, and Pennington Counties. A small yield of lode gold was made from the Hill City district, Pennington County, and considerable development was done in the Keystone district, and several small shipments were made.

One of the problems investigated in the Black Hills of South Dakota concerned the possibilities of erecting and operating a custom mill at Deadwood. The Mogul, Golden Reward, and Reliance mills treat custom ores and were willing to help further. Transport of ore also received attention. Litigation closed the Rattlesnake Jack mine and mill, a valuable property.

South Carolina.—The Walhalla district, in the Blue Ridge Mountains of western South Carolina, was a large gold producer in the early days. The region is described[1] by F. P. Peterson and F. H. Flynn. All indications point to gold deposits of economic value. Profits were made from free gold in leaded surface ores, but combined gold in the deeper sulphides has resisted the efforts of the local people.

Texas.—This State produced $600 in gold and 680,000 oz. of silver, a decrease of $900 in gold and 5000 oz. of silver. The greater part of the output of silver came from the Presidio mine in the Shafter district, Presidio County. Some silver was produced in the Allamoore-Van Horn district, Culberson County, and some from the Sierra Blanca district, El Paso County.

Utah.—Out of a total value of $97,000,000 for all metals in 1916, Victor C. Heikes estimates a gold output of $3,647,000, against $3,609,109 in 1915. Most of the increase is probably derived from copper ores, as the gold-producing districts were not very active. Bull Valley, Sheep Rock, Annie Laurie, and West Mercur mines each produced a little gold bullion. The placer gold production in the State is negligible.

The production of silver is 8 per cent. greater, increasing from 12,313,205 to 13,357,000 oz., amounting to an increase in value of over $2,500,000. Among the silver mines the Ontario was producing ore of shipping grade, and a large increase may be made from the Cottonwood districts. In the Tintic district silver ores will benefit by the chloridizing-roasting process, which was put in successful operation, treating ore and

[1] *Eng. Min. Jour.*, **101,** 377 (1916).

old dump material from the Iron Blossom, Dragon, Swansea, and Black Jack mines. Precipitates high in silver were produced and averaged a car a month before the increase of 100 to 300 tons in the roasting capacity of the plant.

In *Bulletin* 620-I of the U. S. Geological Survey, B. S. Butler and G. F. Loughlin covered a reconnaissance of the Cottonwood-American Fork region of Utah. Besides copper and lead, the output of gold and silver from 1867 to 1913, inclusive, was 21,474 oz. and 10,778,917 oz., respectively, from the Cottonwoods; and 12,869 oz. of gold and 1,791,987 oz. of silver from American Fork. These figures show what is possible when all the properties starting to produce and under development are well opened, and transport facilities are arranged. The main types of deposits are contact, fissure, and bedded, of common origin, showing complete mineralogical graduation. At several places contact deposits pass into fissure deposits.

Washington.—The mine production of gold increased from $391,419 to $540,000. The greater part of the gold was derived from the siliceous ore shipped to smelters from the Republic district of Ferry County. The cyanide mills were not operated, according to C. N. Gerry.

The silver output of Washington mines increased from 255,837 to 315,000 oz. Owing to the advance in average prices of silver, the value of the output increased from $129,709 to over $207,000. The greater part of the silver came from copper ore and concentrates shipped from the Chewelah district, in Stevens County; a smaller amount was derived from siliceous ores mined in the Republic district.

Owing to lack of transportation, difficulty in treating complex ore, and the decline in the price of silver, production has been small in the Conconully and Ruby districts of Washington, near the Canadian border. The minerals carry silver and a little gold. *Bulletin* 640-B of the U S. Geological Survey detailed the local conditions.

Wyoming.—Little new is reported from this State in the way of precious metals, the oil fields being the center of attraction at present.

The Atlantic gold district and the North Laramie Mountains of Wyoming were described in *Bulletin* 626 of the U. S. Geological Survey by A. C. Spencer. The elevation of Atlantic is 7683 ft. and the center is 25 miles from rail. Placer gold was found in 1842. Small stamp-mills —12 with 161 stamps—were erected to crush quartz in 1871. To 1911 placers yielded $1,725,000, and lode mines $4,137,000. On account of lack of nearby rail transport the immediate outlook for a general revival is not encouraging. The veins are believed to persist in depth. Development, ore treatment, transport, and power are the main considerations for success there.

Gold and Silver Mining in Foreign Countries

Africa

Rhodesia.—There will not be much difference in the gold output of this African colony, when compared with that of 1915. The average monthly yield was £327,000 against £318,000 in the previous year. The important mines are as follows, with their monthly yields:

Antelope, 3850 tons for £3870; Bell Reef, 3770 tons for £5100; Cam & Motor, 11,710 tons for £16,450; Eldorado Banket, 4380 tons for £10,300; Falcon, 19,170 tons for £12,440; Gaika, 2950 tons for £4840; Giant, 8800 tons for £3260; Lonely Reef, 5000 tons for £5400; Shamva, 45,030 tons for £35,000; and Wanderer, 13,680 tons for £6080.

Of special interest was the long-drawn-out suit of the Amalgamated Properties *vs.* the Globe & Phoenix Co., involving extra-lateral rights. After 144 days in court in London the judges gave judgment in 2 hr., deciding for the defendant. The action cost $500,000. One benefit of the suit was the stimulation of the study of structural geology of gold deposits in Rhodesia. The Globe & Phoenix is the largest producer, yielding 9500 oz. from 6300 tons of ore, per month, making $125,000 profit.

Transvaal.—The monthly gold yields of the Rand during 1916 averaged approximately as follows: 9250 stamps and 310 tube mills reduced 2,370,000 tons of ore containing 6.26 dwt. gold per ton, yielding £3,170,000. The total for 1916, £38,000,000 was an increase of about £700,000. The working cost was 18s. 1d. ($4.34) per ton. The working profit per ton was 8s. 2d. ($1.96). Dividends totaled £7,300,000, a decrease of £525,000. The principal producers averaged about as follows, per month:

Mine.	Tons.	Ounces.	Profit.	Mine.	Tons.	Ounces.	Profit.
Aurora West United	14,730	4,311	£4,064	New Goch	30,650	6,822	£8,197
Bantjes Consolidated	23,080	5,851	Loss. 783	New Heriot	13,200	5,812	8,623
Brakpan Mines	58,600	22,191	35,010	New Kleinfontein (Apex Section).	21,620	4,641	Loss. 2,882
City and Suburban	27,150	12,089	19,107	New Kleinfontein (New Kleinf't'n Section)	51,200	16,508	23,141
City Deep	59,500	28,481	58,494	New Modderfontein	53,500	26,243	60,866
Con. Langlaagte	54,000	15,168	22,061	New Primrose	22,100	4,060	2,909
Con. Main Reef	27,560	10,217	14,079	New Unified	14,000	3,184	3,894
Crown Mines	203,000	56,938	68,630	Nourse Mines	38,000	14,309	10,679
Durban Roodepoort	14,416	3,403	3,002	Princess Estate	22,400	6,719	741
Durban Rood Deep	25,900	8,195	2,816	Randfontein Central	185,712	58,311	80,036
East Rand Prop	155,500	45,762	44,729	Robinson	56,300	16,752	30 071
Ferreira Deep	53,580	21,469	37,671	Robinson Deep	53,500	17,981	23,562
Geduld Proprietary	26,800	9,621	11,801	Roodepoort U. M. R.	32,223	7,443	2,041
Geldenhuis Deep	57,600	17,599	14,084	Rose Deep	60,000	16,638	16,042
Ginsberg	15,265	3,510	1,974	Simmer & Jack	67,700	17,882	20,232
Gleneairn Main Reef	20,710	3,228	1,002	Simmer Deep	64,700	14,065	4,888
Govt. Gold Min. Areas	64,000	20,842	25,079	Van Ryn	37,400	11,037	18,367
Jupiter	22,400	5,783	3,746	Van Ryn Deep	42,500	20,700	48,947
Knights Deep	102,400	18,239	14,103	Village Deep	51,900	18,109	21,951
Langlaagte Estate	49,328	14,099	13,199	Village Main Reef	29,300	10,238	16,025
Luipaardsviel Estate	20,390	5,525	2,767	Vogelstruis Estate	11,282	3,042	Loss. 1,265
Main Reef West	25,470	6,877	2,766	West Rand Con	33,500	9,039	5,505
May Consolidated	13,170	2,286	645	Witwatersrand	42,100	12,777	21,350
Meyer and Charlton	14,457	8,520	22,155	Witwatersrand Deep	40,000	11,420	13,050
Modderfontein B	43,500	22,800	55,785	Wolhuter	35,000	10,639	13,694
Modderfontein Deep Levels	40,400	18,094	43,680				

Returns for the past 16 years are as follows, in ounces and pounds sterling:

	Oz.	£.		Oz.	£.
1901	238,994	1,014,687	1909	7,280,545	30,925,788
1902	1,707,661	7,253,665	1910	7,533,843	32,001,735
1903	2,955,749	12,589,248	1911	8,237,723	34,991,620
1904	3,779,621	16,054,809	1912	9,124,299	38,757,560
1905	4,897,221	20,802,074	1913	8,794,824	37,358,040
1906	5,786,617	24,579,987	1914	8,378,139	35,588,075
1907	6,451,384	27,403,738	1915	8,772,919	37,264,992
1908	7,052,617	29,957,610	1916	8,972,000	38,110,000

Outside districts of the Transvaal had average months of 52,000 tons of ore, 28,000 oz. of gold, and £24,000 profit. Seven companies contributed to this.

About the middle of 1916, the Government mining engineer, R. N. Kotze, submitted to Parliament of the Union of South Africa a memorandum on the Far East Rand. This area includes all the ground containing the Main Reef series, and situated east and southeast of and including the farms Rietfontein No. 11 and Witpoortje No. 12, and extending up to the limits of the outcrop and sub-outcrop of the Main Reef series. Estimates show that over 203 sq. miles of the "reef" lies at a depth of less than 5000 ft.; only in the southwest corner is it lower than 7000 ft. In the area are four outcrop and seven deep-level companies producing 4,950,000 tons of $7.75 ore per year, yielding $2 per ton in dividends. To the end of 1915 these mines had produced $200,000,000. They are adequately provided with capital. The remainder of the area will require $4800 per claim (1½ acres), or $240,000,000 for the lot. A prudent financial policy is necessary for development of this ground. There will become available 65,000 claims for leasing. The Far East Rand is gently undulating country, and affords good facilities for surface equipment. The coal measures cover the greater part of it. Dolomite underlies this, resulting in a good deal of water, the quantity bailed or pumped per 24-hr. day being from 83,000 to 1,952,000 gal. The cost of shaft-sinking, according to figures covering depths of 1057 to 3777 ft., is from $135 to $240 per ft. The dip of the reef is slight. Mining and drilling shows that over almost the whole area only one reef has been or is likely to be worked. There are three exceptions to this. Of the areas available for leasing, the most attractive and suitable are those lying alongside proved payable mines such as the Brakpan, Geduld, and Springs. Up to the end of 1915 the average recovery from the region was $7.65 per ton. With productive lives of 20 years, and depths of 3000 and 4000 ft., the minimum areas of leases should be 1445 and 2445 claims, respectively. The crushing capacities would be 650,000 and 1,100,000 tons per annum, and total expenditure to reach this point $5,000,000 and $9,500,000. There would be at the start five and seven non-productive years, during development and preliminary work. In 1909 the Government called for applications for the right to mine on two areas, for which Barnato Bros. applied, the subsequent company formed being the Government Gold Mining Areas (Modderfontein) Consolidated, which has been a great success. Others followed. To facilitate leasing and define the Government's profits tax, section 46 of the existing Gold Law is to be amended. Mr. Kotze considers it a matter of urgency to the Union that the Far East Rand be rapidly opened, as, after allowing for all contingencies the area should yield £450,000,000 ($2,200,000,000), and new mines are needed to take the place of those being exhausted on the Rand proper.

H. Foster Bain, former editor of *The Mining Magazine,* who visited the Rand in 1916, examined and criticized[1] the "far-reaching proposals" of the Government Mining Engineer, as outlined above. The Far East Rand is the greatest known gold field in the world remaining to be developed, and its future is discussed by mining men in Johannesburg, London, and New York, when gold production is mentioned. The rate at which the region is opened will depend not solely upon the ordinary laws of economics, but upon these laws and the policy of the Union of South Africa. Almost absolute control is in its hands. The Government needs money for its future responsibilities, and increasing the productiveness of the country is the sound and statesman-like policy. The most immediate field for development is gold mining, and, specifically, the Far East Rand. Mr. Kotze's memorandum is a technical monograph of a high order of excellence. It is thought that the reason the Rand mining "houses" have not done business in the Far East Rand is that it is better to wait until better terms are offered by the Government, this being indicated by the fact that Mr. Kotze recommended that the gold law be changed so as to make tenders more inviting. But Parliament adjourned without taking action on the report of the Select Committee that was appointed to investigate. The financial aspect of operating on the Far East Rand is more involved than appears at first glance, several factors entering into the problem. Mr. Bain concludes by saying that "The Union of South Africa holds, in a certain sense, in trust for the world, a great resource. . . . It is to the general public interest that the output of gold on the Rand should at least be maintained at its present standard as long as possible. To do this requires the opening of more Far East Rand mines."

About October, 1916, the Legislative Assembly appointed a Royal

[1] *Min. Mag.*, **15**, 84 (1916).

Commission to inquire into and make suggestions with regard to the advisability of State mining, the financing, organization, and control of State mines if such are created, and the legislative steps that would be required. Witnesses examined were not in favor of State mining. An apparent deadlock was evident in November, caused by the financial problems, one of which was the Government share in future profits of the companies. A definite plan was suggested[1] by Ernest Williams, an engineer of wide experience. He suggested that the State sink twin or triple shafts (concrete-lined elliptical) at some suitable central point, and construct the necessary underground station; that these shafts should serve a wide area of ground far more extensive than any at present operated by any existing company; and that this area should be subdivided into sections suitable for exploitation by individual companies, these sections being connected with the shafts by main haulage-ways in the foot-wall country. The ground would be leased in sections to such financial groups as are prepared to make suitable offers. Shaft accommodation, already provided, would greatly reduce the capital outlay for individual companies. The scheme is sound, reveals no drawbacks, and demands attention. The southwest corner of the unproclaimed Government farm "Springs" could be taken as the central point of a representative area for this purpose.

During December the Central Mining & Investment Corporation reported that the Government had accepted its tender for the ground east of the Modder B, and its incorporation in a new company to be formed to take over the Cloverfield and Rand Klip Cos. The sum of £1,200,000 is to be raised. The royalty will be 10 per cent. plus the 10 per cent. tax. The Brakpan company tendered for 1812 claims adjoining its own property, and agreed to spend £850,000. In addition to the 10 per cent. profit tax, the company will pay 5 per cent. on any profit made during the next 5 years, thereafter a sliding-scale royalty with a minimum of 12½ per cent. No American tenders were received. The American Rand Syndicate of New York—formed by A. Lewisohn, associated with Lewis & Marks of London and Johannesburg, which firm controls the East Rand Mining Estates, in turn possessing rights on a large tract of the Far East Rand—sent Messrs. Mein, Hoffman, and Searles to investigate the potentialities of the region. American capital may be invested in the region, but so far little has been made known of whether this is to be done.

In a paper read before the Institution of Mining and Metallurgy in February in London, E. T. Mellor, who has had every opportunity to study its mines, went deeply into the conglomerates of the Witwatersrand. In this paper he discussed the arguments relating to the placer and infil-

[1] *Min. Mag.*, **15**, 282 (1916).

tration theories of the origin of the gold. Mr. Mellor considered that the gold was first deposited in a delta, and after the conglomerates were formed and consolidated, the metal was subsequently dissolved by solutions, to be re-deposited nearby. He enlarged on these points in his paper, covering the general stratigraphy of the Witwatersrand system, the physical characteristics of the "reefs," a comparison with the placer

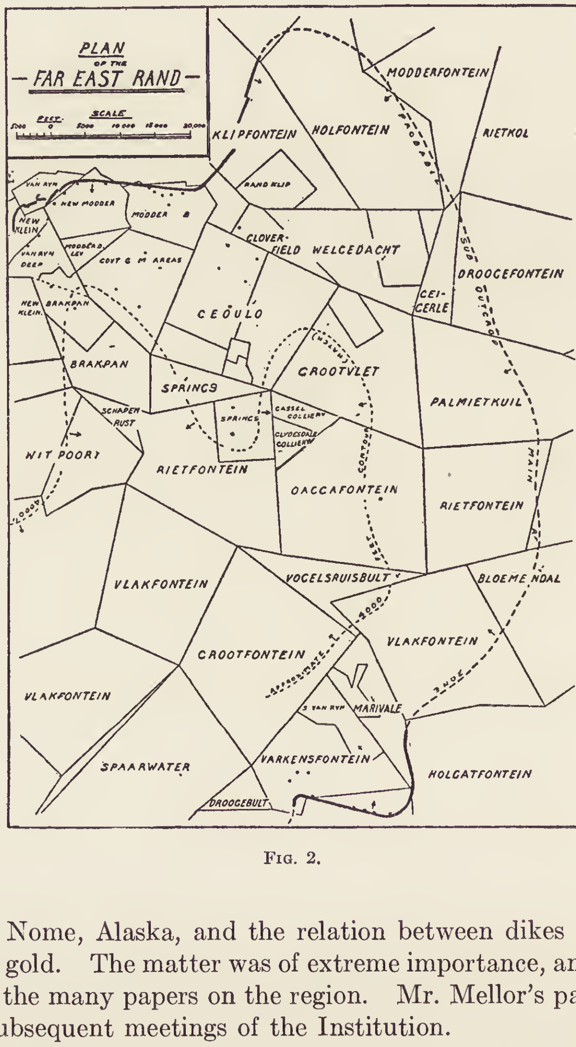


FIG. 2.

deposits at Nome, Alaska, and the relation between dikes and the distribution of gold. The matter was of extreme importance, and a valuable addition to the many papers on the region. Mr. Mellor's paper was discussed at subsequent meetings of the Institution.

Four diamonds were found early in 1916 in the banket of the Simmer Deep mine. Stones had previously been found in other mines of the

Rand. These four stones weighed 1⅝ carats, say 4 grains, and were almost complete crystals. The occurrence of diamonds, iridosmine, and other rare minerals with the conglomerates appears to E. T. Mellor to strengthen considerably the argument in favor of the alluvial origin of the gold. The water currents that laid down the conglomerates of the Main Reef zone did actually carry such heavy minerals as are likely to travel in company with alluvial gold.

Earth tremors or shocks have worried Rand operators for some time, more especially in recent years. An investigation was ordered, and the Witwatersrand Earth Tremors Commission issued its report toward the middle of 1916. The shocks are of sufficient violence to be felt distinctly as a bodily sensation, and are sometimes accompanied by noises resembling thunder. Heavy shocks are felt in the mines themselves. These earth tremors are not the result of earthquakes. The Commission found a sufficient and sole cause for the shocks in the extensive underground operations, especially in the central Rand. Suggestions were made for decreasing the trouble. If a modification of existing mining methods resulted in greater safety and economy, also lessening the number and danger of shocks, some steps should be undertaken to avoid the menace. In mining at 4000 and 5000 ft. on the Rand there have been several difficulties. Pillars are no good for support of the hanging wall, so sand-filling of stopes is increasing in vogue.

When a mining region employs over 20,000 whites and 200,000 natives, labor problems are bound to be many; this is always so on the Rand, the labor situation being ever uppermost. In the September, October, and November issues of *The Mining Magazine*, H. Foster Bain analyzes and discusses these problems. The largest single item in the cost of production on the Rand is that paid for labor, namely 54 per cent. direct cost, plus 6 to 12 per cent. for indirect items, a total of 60 to 66 per cent., or about $1.25 per ton of ore treated. The labor cost per ton is not notably low when contrasted with other countries, considering the low wages paid the Kaffirs. The native labor is of low efficiency, and requires highly paid white supervisors. The recruiting of so many natives is expensive and troublesome. Legally, they are in the position of contract laborers, signing an agreement for 6, 9, or 12 months. The natives are peculiarly subject to lung diseases, and great efforts have been made to preserve the health of the colored laborer. Mr. Bain covers the mortality rate, improved working and sanitary conditions, rations, etc., also conditions in the Belgian Congo. Inducing trained white miners to come to the Rand and securing a local (Boers and British) supply of white workers is another problem. There is a latent supply of the latter in South Africa. Mr. Bain then discusses the education of whites for higher positions, salaries attainable, sociological movements, and lowering or abandoning the color bar.

Efficiency of Rand operators has increased during the war, but the presence of native labor tends to a decrease in the efficiency of the white employees. The normal ratio of whites to natives is 1 to 8; now it is 1 to 10, and it is to be hoped that the companies will retain permanently some of the benefits derived from the enforced improvement due to the present situation.

Phthisis is prevalent at Rand mines, due to rock particles entering the lungs of miners (white and black) and considerable investigation has been made into methods of allaying dust. Over 5000 machine-drills are used in the mines, which naturally make much dust in boring. The Transvaal Miners' Phthisis Prevention Committee issued a report on its observations. The number of injurious dust particles in measured volumes of air shows that, after blasting, the number of particles in the mine air breathed by a miner in a minute can be reduced by water-spraying from 2,450,000,000 to 1,000,000 particles.

The Union Government of South Africa imposed a special war levy of $2,500,000 on Rand mines in 1915, this amount to be levied annually during the war. No protest was made. These mines support the Transvaal[1] and contribute heavily to the support of the Union.

"Which is the world's greatest gold mine?" is a question often asked. This is answered by T. A. Rickard in two editorials[2] in which are an array of figures to prove his contention that the New Modderfontein, in the eastern part of the Rand, is the greatest, when its past, present resources, and future assured profits are considered. With all respect for this conclusion, it may be said that it is doubtful whether the Homestake in South Dakota is not the greatest, although Mr. Rickard considers it the greatest low-grade mine ever exploited by man. The Alaska Treadwell, Juneau, and Gastineau properties were not included. The New Modder has produced $39,745,076 from 4,816,680 tons of ore, and paid $12,247,250 in dividends. Reserves are 19,000,000 tons of ore, and crushing 1,000,000 tons per year, the 20 years' life should yield $125,000,000. The mines compared in this investigation were the Cason, Robinson, Robinson Deep, Village Main Reef (Transvaal), Oroya-Brownhill, Great Boulder Proprietary, Golden Horse-Shoe (Western Australia), Mysore and Champion Reef (India), Waihi (New Zealand), Esperanza (Mexico), Camp Bird (Colorado), Mt. Morgan (Queensland), and Homestake (South Dakota). Nine years ago the Robinson, Waihi, and Homestake were considered the world's greatest gold mines.

[1] *Min. Mag.*, **15**, 70 (1916).
[2] *Min. Sci. Press*, **113**, 332 and 654 (1916).

The big Rand producers are discussed editorially in *The Mining Magazine* of April, 1916. These are the Crown Mines, Randfontein Central, and East Rand Proprietary. During 1915 they treated 2,497,000, 1,983,600, and 2,466,520 tons of ore respectively, giving a working profit of £1,146,552, £600,991, and £644,399. Dividends from these profits were only £611,068, £275,163, and £108,592, equal to 65, 11¼, and 2½ per cent. on the respective capitalization. These three companies were formed to consolidate other companies and interests, but estimates of profits were not realized, as is now well-known.

West Africa.—Gold yields have been falling off during the past few months, when compared with similar periods of 1915. The total will be about £1,580,000 for 1916, against £1,706,473 in 1915. The principal producer is the Ashanti Goldfields Corporation, which, in its financial year ended June 30, 1916, treated 136,994 tons of ore for £482,975 and a profit of £173,281. The last figure was a gain of £13,625 over the previous year. Dividends totaled £154,428. All costs totaled 44s. 11d. ($10.78).

According to W. R. Feldtmann, gold mining is an ancient industry in West Africa, in his introduction to an article[1] describing the mines of the Ashanti Goldfields Corporation. This concern was formed in 1897. Adverse conditions have been many, including transportation, native troubles, distance from source of supplies, labor, and climate. The output to the end of 1916 totals several millions. Schists, intercalated with and traversed by igneous intrusions, predominate. There are several zones of fissuring striking W. 30° E., one of which may be regarded as the axis of the principal gold deposits. In the Ashanti mine the ore-bodies in the main fissure have always been somewhat erratic. The main vein is a solid quartz body, 1000 ft. long on some levels, and from 3 to 40 ft. wide. Gold-content is irregular, and at the lowest levels there is little profitable ore exposed. The Obuasi shoot, which consisted mostly of rich makes of rich quartz-lenses in a graphitic fissure, developed into a much more continuous and regular deposit. The quartz is held in bands of graphitic schist, and is generally of banded structure owing to the inclusion of thin layers of graphitic material. Some gold is free, the remainder being in iron pyrite and other sulphides. The graphitic selvedge on the foot wall is treacherous if wet, and necessitates careful mining. The Ayeinm deposit is in the same main fissure as the Ashanti, and is pear-shaped in horizontal section, being 700 ft. long and from 4 to 60 ft. wide. The grade is low, and where the vein is widest gold-content is erratic. Ore extraction costs $2 per ton, and $1.50 for development.

[1] *Min. Mag.*, May, 1916.

Asia

Considering this great continent from a mining standpoint there is nothing important to chronicle, but it must be said that the potentialities are large.

China.—Chinese mining legislation was the subject of a paper read before the Institution of Mining and Metallurgy in London by W. F. Collins. It would appear that the Chinese are beginning to realize that foreign mining enterprise is desirable. The educated Chinese, who have studied in America and Europe, are the natural leaders in any friendly effort to join in exploiting the mineral resources of China. Mining rights in Manchuria were granted to Japanese, and others ought to be similarly treated. Regulations made in 1904, 1907, and 1914 were found impracticable. The editorial[1] commenting on the regulations was discussed by K. C. Li and M. B. Yung, who agreed in the main that new laws were necessary and foreign capital was desirable, given full freedom of control, but under the Chinese law.

Early in 1916, G. G. S. Lindsey of Canada was asked to draft a new set of laws for the Chinese government.

In describing[2] the metalliferous mines of Hunan province, China, A. S. Wheler, who resigned as inspector-general of mines in China at the end of 1916, gives notes on the gold deposits. There are many evidences of washing river sands, but there is little being done at present, there not being much profit in operations. About 120 miles northeast of Changsha are the principal mines. There are numerous small workings on the hillsides, but work was badly done. The formation is a gray schist, containing quartz veins. The Hunan Official Mining Board controls a number of scattered mines, six of which yield ore by crude methods. The gold output is 120 oz. per month. Other gold mines exist at Suo-sha-po, Liu-lin-cha, and Huitung. The second-named district produces 100 oz. per month.

Under the caption of "An Engineer's Travels in Western China," J. A. T. Robertson[3] writes on the mineral districts of Sze-chuan, which should, in the near future, afford opportunities for the introduction of foreign capital. This province has an area of over 200,000 sq. miles, with a population of 60,000,000. The mineral deposits have been barely touched. The upper Yangtze River gravels are worked for gold by the Chinese, and the other gold deposits are fairly near coal.

India.—Gold is practically all extracted from mines of the Kolar field, State of Mysore. Compared with 1915 there has been a small decrease,

[1] *Min. Sci. Press*, **112**, 330 (1916).
[2] *Min. Sci. Press*, **112**, 337 (1916).
[3] *Min. Mag.*, **15**, 265 (1916).

the monthly yield being £191,000 in 1916, against £197,000 in 1915. However, the future of the large mines is fairly good, in spite of poorer development at depth. Monthly outputs were somewhat as follows: Balaghat, 2300 tons for 1480 oz.; Champion Reef, 13,065 tons for 9300 oz.; Mysore, 26,929 tons for 16,480 oz.; Nundydroog, 8500 tons for 6820 oz.; and Ooregum, 13,320 tons for 7705 oz.

Silver in large quantities will soon be produced by the Burma Corporation, which is operating the Bawdwin mines in Burma, India. Over 3,000,000 tons of ore is in reserve, containing 25 oz. per ton of silver, besides high zinc and lead-content. A 1000-ton mill is being erected.

Japan.—Japanese gold and silver mining has been aided by the war. New mines were opened early in the year, and the output of those in the Province of Idzu increased. The properties of the Mitsui Mining Co. and Fujita Gumi also improved.

According to H. W. Paul of Yokohama there was an increase of 125 per cent. in the number of applications for mining concessions (all minerals). In the January-September period the gold output fell off 3.5 per cent., and silver 10.2 per cent.

Little news is obtainable from this country until late in the year, and as nothing of importance transpired, it is not necessary to dwell upon the country further; but following will be found interesting notes on a Japanese province, namely, Chosen (Korea):

Korea.—In the course of a long paper contributed to the Korean branch of the Royal Asiatic Society, the history and present position of gold mining in Korea was given by E. W. Mills, who has personal knowledge of all the gold districts during 13 years' experience. The development of production in recent years has been rapid. In 1895 the output first passed the £100,000 (£1 = $4.85) mark, while in 1913 it was valued at £1,035,391, in 1914 £1,023,398, and in 1915 it attained the record yield of £1,229,621. Gold mining is of ancient origin in Korea, this being, however, entirely alluvial, and it has been overshadowed of late by the development of lode mining under modern conditions. The first concession to foreign engineers was the Morse in 1895. Subsequently, concessions were granted to British, German, French, Russian, Japanese, and Italian representatives.

The Unsan Concession is now being worked by the Oriental Consolidated Mining Co., an American company, which has been highly successful in its operations in this district from the beginning. The mill at Chittabalbie was the pioneer of the modern stamp-mills in Korea. The growth and development of this concession has been exceedingly satisfactory. On July 1, 1915, a total of 210 stamps was in operation at the following mines. The total tonnage of ore produced from the various mines since

1897 to Dec. 31, 1915, has been 3,986,772, valued at Y49,568,632 (Y1 = 50 cts.). To July 1, 1915, total dividends have amounted to Y12,871,550. The Suan Concession, a British property, is held by the Korea Syndicate, of London, but is being operated by the Seoul Mining Co. This concession is being developed with highly successful results. Although not as old as the Unsan, its tonnage and output are increasing yearly. It shows promise of eventually becoming the largest producer in Korea. The first mill of 20 stamps was placed in operation in the latter part of 1909 at the Suan mine. This mine developed satisfactorily, and the mill was increased to 40 stamps in the autumn of 1911. During the past 3 years a larger mine than the Suan mine has been developed at Tul-mi-chung, 6 miles south of Holkol. A reduction plant, the pioneer of its kind in Korea, was placed in operation late in September, 1915. This plant has a rated capacity of 350 tons in 24 hr., and is the first one in Korea to use Hardinge ball and pebble-mills, in place of ordinary gravity stamps, for crushing and grinding ore. Both plants also employ the oil-flotation process for the recovery of concentrate. It is expected that the production of gold from the Suan concession for 1916 will approximate a total of Y2,500,000. Since the date of the commencement of milling operation in 1909 to Jan. 1, 1916, the Suan concession has produced 433,361 tons of ore, valued at Y7,945,328, with a total gold production of Y6,566,244. Dividends for the same period amounted to Y2,180,087, or a total of 275 per cent.

The Chiksan Concession was operated intermittently by the concessionaires, Shibusawa-Asano Mining Partnership, on a small scale until 1906. In this year American partners were admitted, and in 1907 a small stamp-mill was placed in operation. In 1911 a reorganization took place, whereby the control of the concession rights was taken over by an American company, the Chiksan Mining Co. During the Japanese régime considerable work was done on the placer deposits, and a small profit was made. Although no exact figures are available, it is probable that the alluvial gold production during this time amounted to over Y300,000. It is estimated that the Chiksan concession has produced Y3,199,073 in gold, and has treated 192,144 tons of ore during the period from February, 1908, to Jan. 1, 1916. This concession has now reached the dividend-paying stage, and is being operated successfully. The present company has proved the existence of a large acreage of ground containing sufficient gold to warrant the installation of a gold dredge at Sei-go-ri, which was worked earlier under the supervision of the Japanese concessionaires. The order has been placed for this dredge, and it is expected that it will be in operation before the end of 1916. Chiksan will, therefore, have the distinction of starting the first gold dredge in Korea.

The operation of this boat, in conjunction with the present mill of 40 stamps, should result in showing considerable increase in the gold production for 1916 and for several succeeding years. It is probable that some monazite may be recovered by the dredge.

Under Government encouragement, an important combination was formed in recent years known as the Furukawa Partnership Co., which holds some 15,000 acres in the Koo-Sung district, north Pyengan. The chief interests comprised are those of Messrs. Furukawa, Asona, and Kuhara. In coöperation with this company, the Kuhara Mining Co. of Osaka, lately completed a smelter at Chin-nam-po, designed primarily to treat gold-copper ores, more especially the concentrate, from the Suan mines. The Japanese government has itself retained a number of gold prospects for experimental working in different districts.

In all, about 50,000 Koreans and several thousand Chinese and Japanese are now dependent on the foreign companies for their livelihood. The author states that Japanese authorities are willing to assist foreign mining companies in every possible way. After the occupation of Korea, mining regulations were issued in 1906, with further amendments in 1907 and 1908, and a further revision is expected to be published shortly. Henceforth it is provided that "none can enjoy mining rights other than subjects of the Empire or juridical persons organized in accordance with the laws and ordinances of the Empire." It is stated, however, that foreigners who already possess mining rights will not be affected by the revision either now or in the future. The author concludes that the outlook for a continued increase in gold production is promising, more especially from the successful development of large, low-grade auriferous deposits.

In April the Japanese Government brought a new mining ordinance into effect in Korea, containing regulations that were not conducive to investment of foreign capital. Those desirous of exploiting mines in Chosen must incorporate a company under the laws of Japan; a technical superintendent can be discharged by order of the authorities; the Governor General can alter plans for working a mine, and if two applications for a given property reach the department on the same day, he can issue the permit to whichever applicant he prefers; and the royalty is 1 per cent. of the total value of the mineral output, plus 25 cts. per acre ground rent, the total value to be decided by the Governor General. These are some of the restrictive clauses, which do not tend to please foreign investors.

Philippine Islands.—The U. S. Mint and Geological Survey estimate that the 1916 gold output was $1,549,600, an increase of $230,000, and 17,900 oz. of silver, an increase of 3000 oz. Dredging and lode mining continued in much the same way as in 1915, with several improvements.

Gold mining in the Philippines was covered[1] in a general way by C. M.

[1] *Min. Sci. Press*, **112**, 900 (1916).

Eye. The Aroroy district produces most of the lode gold in the Territory. The Colorado is the largest mine, yielding a profit of $230,000 from 50,000 tons of ore per year. The Syndicate mine is next, followed by the Keystone. The Benguet district ranks next to Aroroy. Here the Benguet Consolidated treats over 1500 tons of $20 ore per month. The Headwaters and Acupan are others in the region.

Russia and Siberia.—The Russian empire may be included under Asia, as most of the mining is either in the Urals or east of them, and future possibilities are mostly in Siberia. Russian gold production has varied during the past 12 years between $22,000,000 and $35,000,000 per annum, the last 4 years showing a gain of about $2,000,000 successively. The latest available figures are $26,750,000 for 1914. The correctness of these Russian gold statistics is open to doubt, as the exact amount of gold recovered is not really known, partly because the department dealing with the industry is not as well organized as our own or those of other countries, and partly because of the legalized theft prevailing in the gold mines, causing a good deal of the product to be smuggled across the border into China, which for many years was credited with a preposterous production of gold. However, the somewhat stationary condition of gold mining in Russia and Siberia, it is reported, has at last attracted the serious attention of the Government, which is showing an inclination to act upon the resolutions passed at the various conferences that have been held in the empire, including the gold and platinum producers, calling for measures of support and stimulation. The area allotted for exploitation of gold has decreased in recent years, also the quantity of gravel treated, for, at present, most of the Russian yield is from placers. Gold is known to exist, in quantity inviting mining, over a million square versts, of which only 5000 versts is being exploited. The Government is being urged to throw open more of the Crown lands for mining exploration, to send geological expeditions into the field, and to facilitate colonization of the known gold-bearing areas. Lack of the means of transport hinders new work even in regions that are open to exploitation. Good roads are wanted, as also the extension of the postal and telegraphic services, which are the nerves of industry. It is said that many old dumps of half-washed gravel, left by operators using crude methods, are available for profitable re-treatment. Lode mining for gold is yet in its beginning, and in this respect affords a curious contrast with the recent growth of activity in copper, lead, and zinc mining, particularly in the Ural, Akmolinsk, and Altai regions. Of course, the war and its financial exigencies should cause the Russian Government to do all it can to stimulate the winning of gold from the ground. We believe that it will, and in doing so that it may find it advisable to draw further on American experience.

Development of Russia's resources was discussed editorially in the June issue of *The Mining Magazine*, in which the history of the introduction of British capital into the empire is covered. For a century, in one way and another, mineral deposits in Russia and Siberia were developed by British money and technical skill, though in a small way until about 1900. Distance, transport, language, and customs were handicaps to more extended interest. Recent investigations have been mostly in base-metal deposits.

"One-man propositions," so numerous in Alaska, are rare in Russia, but there are many areas suitable for such work. Alaska and Siberia are along similar lines of latitude, and there is no reason why the latter country should not have such operations. At present most of the one-man operations are done secretly and illicitly, owing to the obstructive and unwieldy laws and the tardiness of their application. What Russian gold mining needs, perhaps, more than anything else, is such freedom of initiative and operation as will encourage one-man schemes to open the country.[1] When once prospected and opened by small-scale operations, working by merged interests on a large scale will follow, automatically, as it has in Alaska and Klondike under similar conditions of climate, transport, and inaccessibility.

Industrial opportunities in Siberia, including notes on gold mining, was the subject of an address of C. W. Purington before the Boston City Club in February, which enlightened many on a little-known country. He said that Siberia is perhaps the greatest untouched field for gold and other metals in the world. In the great Alatau, Altai, and Sayan Mountains is a vast territory waiting to be explored.

Winter sluicing at the Lenskoi (Lena Goldfields) gold mines, Siberia, was an interesting subject detailed[2] by C. W. Purington and R. E. Smith. The system of washing the gravel in sluices from 175 to 275 ft. in length was introduced there less than 3 years ago, supplanting previous methods. Underground drift-mining is carried on throughout the year, producing dumps of 400,000 cu. yd. or more. The re-handling of this material was expensive in the washing season, and all-the-year washing was desirable. For 4 decades the company had done no washing in the winter. First trials were made in the winter of 1913–14, in old plants, with success. The Alaska type sluice with 10 per cent. grade was tried in 1914–15, also successfully, while others were erected in the autum of 1915. They were covered for protection against the weather. The amount of winter dumps has been reduced considerably, and costs were decreased 50 cts. per yd.

In addition to copper, coal, platinum, and iron, the Ural region between Russia and Siberia contains gold deposits of promise, according to T. H.

[1] Editorial, *Eng. Min. Jour.*, **101**, 364 (1916).
[2] *Min. Mag.*, **15**, 143 (1916).

Preston.[1] The area is 120,000 sq. miles. Mining has been prosecuted for 500 years. The Urals produce 95 per cent. of the world's platinum. Gold is found and mined from quartz veins in limestone, and metamorphic rocks, from alluvium, and old river beds, and as a by-product from copper ores. In the Kochkar district, wherein are the best-known gold deposits, the veins intersect a granite belt, itself containing free gold. Also near Ekaterinburg the metal occurs in small quartz stringers cutting through a huge granite lode called "beresite." River beds and alluvium have received considerable attention, the veins little until recently. In 1913 the gold yield of the Urals was 217,664 oz., about the same as the platinum. Dredges have been successful. The placers are extensive, and comparable with those in Siberia.

Australia

Owing to the impoverishment of the auriferous deposits of the older fields such as Bendigo, Charters Towers, Kalgoorlie, Gympie, Waihi, and others, the gold yield of the Commonwealth of Australia and Dominion of New Zealand continues to drop, the decrease in 1916 being nearly 400,000 oz. Conditions generally, owing to the war, are against the industry. No new fields have been found, and prospecting is at a low ebb, although in the Western State there was some prospecting enthusiasm, aided by the Government. In value the 1916 gold production was £8,301,008, representing a decrease of 16.8 per cent. from 1915.

The following table shows the gold output over a series of years:

PRODUCTION OF GOLD IN AUSTRALIA (*a*)
(In fine ounces)

State.	1909.	1910.	1911.	1912.	1913.	1914.	1915.	1916.
New South Wales	204,709	188,857	181,121	165,295	149,657	124,507	132,498	108,144
Northern Territory	5,682	5,109	(*e*) 5,000	(*e*) 5,000	(*e*) 4,600	(*e*) 4,500	2,532	(*e*) 1,540
Queensland	455,577	441,400	386,164	347,946	265,735	248,395	249,360	223,164
South Australia	7,111	6,603	3,537	6,592	7,292	6,000	6,258	(*e*) 5,800
Tasmania	44,777	37,048	31,101	37,973	33,440	27,320	18,547	17,981
Victoria	654,222	570,383	504,090	480,131	434,932	409,706	329,068	256,643
West Australia (*b*)	1,576,406	1,422,231	1,338,987	1,282,658	1,314,044	1,232,974	1,210,109	1,061,398
Commonwealth	2,948,484	2,671,631	2,449,910	2,325,595	2,209,700	2,053,402	1,948,372	1,674,670
New Zealand (*c*)	472,465	446,434	427,385	310,796	343,627	(*e*)361,272	(*e*)422,825	292,620
Total Australia	3,420,949	3,118,065	2,877,295	2,636,391	2,553,327	2,414,674	2,371,347	1,967,290

(*a*) From official publications. (*b*) Production reported by the Mines Department; in previous volumes the statistics have represented exports. (*c*) Exports. (*e*) Estimated.

Although Australasia produces over 13,000,000 oz. of silver annually, there are no mines operated as silver producers, the nearest to this point being in the Waihi district of New Zealand. The remainder of this metal is a by-product from the copper, lead, and lead-zinc mines of New South Wales, Queensland, and Tasmania.

[1] *Min. Mag.*, April, 1916.

New South Wales.—This State is essentially a lead, zinc, copper, and silver producer. The gold output is erratic, varying from £18,000 to £39,000 per month. The largest producer is the Mt. Boppy, which makes a return of 2000 oz. from 5600 tons of ore. Broken Hill produces the bulk of the silver of the State, and most of that in Australia, being recovered from the lead-zinc ore. The gold output of the State in 1916 amounted to £459,370.

New Zealand.—The gold and silver output of the Dominion did not equal that of 1915, as several mines have shown a decline. The gold production was £1,199,212, a decrease of £495,341. Apart from dredging and hydraulicking in the South Island, the precious-metal yield depends on such mines as the Waihi (15,230 tons for £26,000 per month), Waihi Grand Junction (9800 tons for £18,200), Talisman (4500 tons for £22,000), and the Consolidated Gold Fields of New Zealand group—Blackwater, Progress, and Wealth of Nations (9000 tons for £16,000).

Queensland.—The average monthly gold yield was 19,000 oz. fine, or 2100 oz. less than in the same months of 1915. The total production for the year was £937,288, which is £123,415 less than the 1915 yield. Fully half of the gold is from the Mt. Morgan mine, which smelts direct 16,000 tons of copper-gold ore, also 3000 tons of concentrates from 12,000 tons of ore treated by flotation per month. During the year ended May 28, 1916, the gold yield was 120,131 oz. from 322,350 tons of ore, etc., smelted. Reserves total 4,333,600 tons containing from $1.02 to $9.81 per ton of gold. Dividends totaled £250,000. Other copper mines, such as in the Cloncurry district, yield gold as a by-product. The Charters Towers, Gympie, and other gold fields had no new development of importance, while outputs decreased. The former in October produced 2377 oz. from 2555 tons of ore and cyanide tailing; the latter 3985 oz. from 10,269 tons. Queensland is a base-metal producer, the monthly output of this being about $1,000,000.

Tasmania.—The precious metal output is mainly from smelting copper ore at Mt. Lyell, where from about 310,000 tons the annual yield is approximately 8900 oz. of gold and 370,000 oz. of silver. The island State of the Commonwealth is essentially a base-metal producer, to which most attention is paid. There are few mines worked strictly for gold, and they are small. The balance of the gold yield, about 8000 oz., is made up from this source, and as a by-product from base metals. The silver output is also from this source, the lead, copper, and zinc ores of the West Coast region. In 1916 the gold production of the State was £75,552.

Victoria.—Gold production of this once great source of gold was erratic during the past year, averaging £90,000 per month, compared with £155,000 in 1915. The total production for the year was £1,090,194.

There does not seem to be anything that can stimulate mining in the State, neither deep exploration, dredging, nor the deep leads. The Bendigo field has a large decrease during 1916.

Deep leads in Victoria have been enormous producers of water and gold in the past, but little is heard of these deposits now. M. T. Taylor read before the Cornish Institute of Engineers in May an account of the methods employed in developing and mining the deep leads. The gravel is covered by an overburden several hundred feet thick, and it is full of water, so that mining and pumping operations are costly. Coping with the water, shaft-sinking, cross-cutting, boring up to the gravel, opening out, panelling, timbering, ventilation, and extraction of the gravel were complicated problems. The average yield per fathom of gravel was $11 at one mine in 1908, costing $6.88 per fathom to recover, of which pumping was $1.80.

Western Australia.—This State contributed the largest decrease to the Australian total. The 1916 production of gold was £4,508,532, compared with £5,150,227 in 1915. The mines of this State are far inland, in an almost waterless and desert country, with little facility for the local production of foodstuffs. The standard of wages has been necessarily high. In 1893 the grade of ore was $14.40 per ton, now it is under $9.60; in 1903 the profit was $4.44 per ton, now it is $1.44. Large tonnages have to be treated to make a decent return on the capital. The war has intensified all of the factors, added to which was the difficulty in securing such supplies as zinc sheets, cyanide, explosives, quicksilver, and special machinery, none of which is made in Australia. Prompt action by the Chamber of Mines at Kalgoorlie saved the situation. Many of the best men employed at the mines went to Europe, resulting in a shortage of labor. The unions acted foolishly, and demanded increased wages. Heavy taxation—old and new—is another grave disability that this State suffers from. The Ivanhoe company continued its pioneer work in exploiting at depth, and is now down 3600 ft.

The principal gold producers in Western Australia had monthly yields during 1916 on about the following basis:

Mine.	Tons.	Value.	Profit.
Associated	9,000	£12,000	£2,000
Bullfinch	6,200	6,500	1,200
Edna May	3,100	13,000	7,000
Golden Horseshoe	19,000	35,000	8,000
Great Boulder Perseverance	17,500	19,000	....
Great Boulder Proprietary	18,000	49,000	25,000
Ivanhoe	20,000	33,000	10,000
Kalgurli	9,100	17,000	5,200
Lake View and Star	17,500	19,000	....
Oroya Links	8,000	8,000	....
Sons of Gwalia	14,000	21,000	5,000
South Kalgurli	9,000	11,500	1,000

Dividends totaled about £500,000.

North America

Canada.—In 1915 the gold output of the Dominion was valued at $19,000,000, but in 1916 this total was exceeded by fully 20 per cent. This was mainly due to the Ontario output of nearly $10,000,000, which was a large gain (nearly 30 per cent.) due to increased operations at Porcupine. Here the Dome yielded $2,125,000 (39,000 tons monthly of $4.70 ore at a cost of $2.80), Hollinger $4,700,000 (50,000 tons of $8.78 ore at $3.74 cost), McIntyre with $1,000,000, Schumacher with $600,000, followed by the Vipond, Dome Lake, and others. During 1917 the Porcupine output will be considerably augmented.

Owing to the war, conditions were not favorable for gold mining, owing to high prices, shortage of labor, and taxes. It seems to be assumed that taxation such as was proposed and imposed in Canada, or such as the English excess-profit tax, affects a gold mine similarly as it does a manufacturing concern; but this is not so, according to F. H. Hamilton.[1] A gold mine is a wasting asset, generally with a relatively short life. A dividend from industrial enterprises, such as 7 per cent. from a railway, has quite a different value to 7 per cent. from a gold mine. All other products can accomodate their price to an increase in cost of production, but gold, being the fixed standard of value, can not do so. All metals save gold have increased in price considerably since the war commenced, likewise commodities, and the real value of gold has obviously depreciated in the same proportion. Therefore, gold mines should not be taxed at the same ratio as other metals and products of manufacture.

The silver production was 25,669,172 oz. in 1916, a decrease of 3.6 per cent. in quantity; the value, however, increased 27 per cent.

British Columbia.—Gold and silver production did not make so much progress as did that of the other lode metals already mentioned. The reasons for this are evident, and the bar to progress but temporary, for the outlook for increased production of these metals in the coming year is decidedly promising. Of the lode gold produced in British Columbia, in 1915, 250,000 oz., and silver, 3,366,000 oz., the Trail smelter of the Consolidated Mining & Smelting Co. contributed approximately 60 per cent. of the gold and 70 per cent. of the silver. This holds good for 1916 also. This is the result of smelting silver-bearing copper, lead, and zinc ores from its own mines and those of other companies in the Province and the State of Washington. The gold and silver from these reduction works is produced electrolytically, a process described[2] in detail by T. A. Rickard, who visited the plant in September. The same writer discussed the opportunities offered capital in the Province. The British Columbia

[1] *Min. Mag.*, March, 1916.
[2] *Min. Sci. Press*, **113**, 903 and 939 (1916).

Copper Co. and the Britannia Mining & Smelting Co. also produce a fair quantity of precious metals, while the Granby Consolidated Mining, Smelting & Power Co. yields over 40,000 oz. gold and 500,000 oz. silver from its copper ore. These four large companies have and are increasing this scope of operations, so that gold and silver production will be greater during 1917. The various copper, lead, and zinc mines in other districts yield silver. Considering the above it might be said that most of the gold and silver output of British Columbia is a by-product of base ores. Placer mining yields a varying amount, though it increases each year, and 1917 should show fully 40,000 oz. The only large gold mine in the Province is that of the Hedley company, the Nickel Plate at Hedley. The mine produces a gold-bearing arseno-pyrite ore occurring in limestone and for years has been highly profitable. The stamp-mill, concentrators, and cyanide-plant treat over 6000 tons monthly of nearly $11 ore. Some interesting problems have been worked out at this mine. Generally speaking, with the greater activity going on in British Columbia, the precious-metal output should increase, a continuance being dependent on the price of the base metals.

Seventeen miles east of Atlin is the Ruby Creek district, and the solution of some hydraulic mining problems encountered there was given[1] by C. F. Lee and T. M. Daulton. The great width of the deposit, flood waters, poor pumping facilities, and large boulders were the difficulties. All costs totaled 47.6 cts. per yd. The output since 1898 is $6,540,000.

Manitoba.—This Province is now showing remarkable possibilities in at least one part of the Province, and has a great expanse of country urgently requiring exploration, according[2] to W. K. Harding, who discusses the field for the prospector in the Province. It rests with the prospector, mining development, and the Government whether or not Manitoba will become a large mineral producer. The yield at present is only 1 per cent. of Canada's total.

In Manitoba, The Pas and Rice Lake gold districts attracted some attention. The former were described[3] by J. S. DeLury, while Canadian Geological Survey officers published memoirs, also. The ores are mostly sulphide replacements or quartz veins in schistose rocks, the ores and veins being generally parallel to the schistosity of the rocks. On the whole, the gold discoveries in this district are remarkable for their number and nature, for the short time, and further work should be worth while. M. De Lury also described[4] the Rice Lake district, and considers that the wide distribution of gold augurs well for future prospecting. W. K.

[1] *Bull. Amer. Inst. Min. Eng.*, May, 1916.
[2] *Min. Eng. World*, **44**, 993 (1916).
[3] *Can. Min. Jour.*, Sept. 1, 1916.
[4] *Can. Min. Jour.*, Aug. 1, 1916.

Harding wrote up[1] the Rice Lake area, which is 30 miles east of the southern part of Lake Winnipeg. The gold occurrence is somewhat similar to that at Porcupine, Ontario.

Ontario.—The year has been a busy one in the gold and silver districts of the northern region. While considerable prospecting and development was reported from outside areas, at Porcupine, Kirkland Lake, and Cobalt the enlargement of mills and improved processes occupied much attention. The gold output of the Province was worth $10,000,000, an increase of 30 per cent.

About 500 miles north of Toronto are the principal mining centers of Northern Ontario, according[1] to A. K. Stewart, who briefly dealt with the

FIG. 3.—Mining regions of Northern Ontario.

geology and mining activities at Cobalt, Porcupine, Boston Creek, Kirkland Lake, and other districts. Present and projected development at Porcupine leads Mr. Stewart to believe that it will have a larger production than Cripple Creek in Colorado within 2 years.

Mining districts of Northern Ontario were described[3] by Robert Livermore, who stated that these may be divided into two classes, the precious-metal and the base-metal areas. The former are in the northern part, and may be divided also into two parts, gold, and silver, with a clear line of demarcation. The geology, production, labor, mining and milling practice are briefly covered.

[1] *Min. Eng. World*, May 27, 1916.
[2] *Min. Eng. World*, **44**, 733 (1916).
[3] *Min. Sci. Press*, **112**, 89 (1916).

The Boston Creek and Goodfish Lake gold areas of Ontario were described in *Bulletin* 29 of the Provincial Bureau of Mines by A. G. Burrows, and P. E. Hopkins. The former place is southeast and the latter northeast of the Kirkland Lake field. Boston Creek is 382 miles by rail from Toronto. Its deposits are: (1) fissure quartz veins in greenstone and porphyry; (2) replacement veins; and (3) stockworks in granite and porphyry. At Goodfish Lake numbers of mines are closed owing to low-grade ore. La Belle Kirkland Mines was the only property being worked in May, 1916. The ore deposit occurs along the contact of quartz-porphyry and basalt. Developments appear to be encouraging.

The Kowkash gold district of Ontario, through which runs the National Transcontinental Railway, has not received much publicity during 1916, although exploration continued. Gold was discovered in August, 1915. The area was again examined by P. E. Hopkins for the Provincial Bureau of Mines early in 1916. He considered that the various claims were worth developing, and the region generally warranted the further attention of prospectors.

The silver production of Cobalt was approximately 21,600,000 oz., a decrease of 2,000,000 oz., but the value was $1,800,000 more than in 1915. With the return of high prices for silver the district showed increasing signs of prosperity. Exploration and search for the high-grade little veins was stimulated. The flotation process was introduced at several mills to reduce losses in the residue, whole old tailing is being successfully treated by this method.

One of the interesting explorations at Cobalt was the sinking of the Beaver and Temiskaming shafts to encounter the lower contact. The upper contact, between the keewatin and diabase, is approximately 500 ft. from the surface. Along this contact, both above and below, these two companies extracted their richest ores. It was calculated that at the lower contact, or along the floor of the diabase sill, equally rich ore as occurred at the upper contact will be found. Drilling done jointly by the two companies determined that the lower contact exists at a depth of 1670 ft. from the surface.

Late in January, 1917, the Beaver Consolidated cut 6 to 8 in. of rich silver ore at 1600 ft. depth in the lower contact. This is most important for the district's future. The Temiskaming shaft is nearly this depth, and the two mines are to be connected.

At their Cobalt properties the upper contact has been eroded, and the lower contact was reached at a depth of 274 and 322 ft., in the Kerr Lake mine. No. 3 shaft produced 5,000,000 oz. of silver just above the contact. This shaft is a mile northwest of the Temiskaming shaft. The

Lawson mine of the La Rose company yielded 2,500,000 oz. below the contact.

Mexico.—Each year conditions in this country get worse, 1916 being a particularly bad one for mining. The revolution continued, political developments grew more complicated, and the Government got into trouble with the United States owing to border conditions. It is safe to say that the gold output of $6,560,000, and silver output of 39,570,000 oz. in 1915, will not be reached by a great deal.

The Mexican-American Joint Commission investigated the disputes between the United States and Mexico during the latter part of 1916. Early in October an influential group of American capitalists having large

FIG. 4.

interests south of the Rio Grande conferred with the Commission regarding their troubles in operating, caused by the continued revolutions and differences with the United States. How the mining and smelting industry in Mexico conducted by Americans suffered can be seen from the following comparative statement, the figures dealing with 45 companies with plants in 14 States:

	First Half of 1916.	Same Period of 1912.
Mexicans employed	6,000	62,216
Aggregate payrolls (U. S. A. currency)	$3,671,302	$18,726,090
Copper matte and bullion, tons	23,156	74,984
Zinc ore, tons	11,183	46,765
Lead bullion, tons	2,928	70,939
Silver, ounces	6,200,339	31,892,735
Gold, ounces	39,895	252,843

This shows a large reduction in every item. Taxes have also increased as follows:

21

	Constitutional Law, 1912.	Arbitrary Decree, 1916.
Pertenencia	$96,629	$569,738
Export and other dues	1,629,971	7,096,052
Total	$1,726,600	$7,665,710

At the end of 1916 the Commission adjourned without coming to any satisfactory arrangements.

Early in February the Department of State at Washington, D. C., issued a notice relative to shipment of munitions of war into Mexico, while the embargo was in force, regarding Chihuahua, Sonora, and Lower California. Without specific authorization from the President, no powder, fuse, dynamite, blasting caps, etc., were permitted to enter those regions. This worked a hardship on mining companies for a while.

Taxes in Mexico lost their immediate interest during the year, as nobody knew a month ahead who would collect them. The Carranza Government in May declared a 10 per cent. export and import tax on gold in any form, and 5 per cent. tax on silver. This was modified temporarily at the end of 1916. Another tax, payable in Mexican gold coin, covering gold and silver properties was as follows: 1 to 10 pertenencias (2½ acres), $6; 11 to 50 pertenencias, $12; 51 to 100 pertenencias, $18; and over 100, $24 per year. A proclamation was also issued, and modified from time to time, demanding that mines be re-opened by foreigners under penalty of forfeiture.

According to letters received from mining engineers still remaining in Mexico, the principal mines at El Oro were working full time at the end of 1916, and the workmen are being paid in silver. Coin is hard to get and a shortage is anticipated despite the premium offered. Small strikes among the men have been settled promptly. While shut down the main object was to keep the mines free from water. All of the companies coöperated to employ 500 to 600 natives, to prevent them from starving and becoming dangerous. Mine workings were kept in good order, and some development was done. No physical damage was done the mines. Taxes are higher, also the cost of labor and supplies. At Pachuca the depreciation of paper money makes business difficult. The Government refuses even to receive its own money in payment for taxes and freight. The mining companies are compelled to use gold and silver, but the scarcity of this means of exchange hampers dealings. Several strikes, due to the inability of the peons to understand the financial situation, have interrupted mining operations, but not for long. Another difficulty is the scarcity of cyanide. This has curtailed the capacity of the mills. Moreover, the exorbitant price of cyanide, caused in part by the withdrawal of large stocks bought by speculators, will render it impossible for the poorer properties to continue at work. The destruction of trains, the strikes among the railway employees, and the raids of bandits render operations so precarious that it is impossible to look ahead. Correspondents in localities so wide apart as Pachuca and Tequila agree that the one thing that would aid the existing Government in restoring order would be a loan. Without money the powers that be are helpless. The latest December decree concerning the export tax on metals made a reduction of 3 per cent. on the gold and silver.

Some instructive letters were written for the *Mining and Scientific Press* during the year by a well-informed correspondent at Mexico City. The first letter discussed inflated currency, famine, pestilence, race prejudice, railroad and bank paralysis, Zapatism, and Syndicalism, really the political situation. The next letter gave the history of Villa's triumph and downfall. In July, another letter covered the financial situation, counterfeiting notes, the huge issue of "unfalsifiable" notes, the revolutionary patriots, and the agricultural position. The last letter of the year, in December, analyzed the banking decree of September, whereby banks of emission (notes) were subjected to extremely restrictive and burdensome regulations. The new paper money issued by the Carranza government decreased in value, until in December the peso was worth only 1.4 cts. U. S. gold, there being no gold to back up the issue. The money was forced on the people, but even the poorest could see the money was practically worthless. Labor troubles at the capital were only put down by harsh threats. The men wanted coin instead of paper for wages. Famine and fever attacked thousands of people in the west of Mexico. Generally speaking, at the end of 1916 conditions in the Republic were no better than a year ago, really far worse, as the Villa army was very active in the State of Chihuahua and other mining regions.

The same writer in January, 1917, further gave inside information on the Republic, also the modified regulations applying to the operation of mines, it having been found impossible to resume work at many under present conditions, the Carranza Government recognizing this. There appears to be no Mexican able to act firmly and regain internal quiet.

"Mexico—What Will the Final Outcome Be," is the title of a review[1] of conditions by an American engineer who was in the country for many years. He concludes as follows:

"Assuming that the European war continues for 4 years more, and that President Wilson makes no change in his Mexican policy, what is likely to occur in Mexico? Disintegration of the Carrancista Government; short-lived attempts by other men to take Carranza's place; growing power of Villa and of Feliz Diaz; more bushwhacking by Zapata; total anarchy in economic affairs and industry in general; more and more losses by foreign interests. And when the limit of endurance has been reached, the foreign, material-interests people will for the first time enter into Mexican

[1] Anon., *Met. Chem. Eng.*, **16**, 10.

politics; will organize for particular interests of Villa, of Feliz Diaz, of the old-time, respected Porfirio Diaz people, with a considerable proportion of foreigners in active service, into a compact, well-equipped organization that will sweep Mexico and will establish a government so strong and so stable that our present American dream of dominating politics from the Equator to the Canadian line will never come true."

South America

Even the average mining man is in doubt when asked as to the occurrence of gold and silver in South America. In the April *Bulletin* of the American Institute of Mining Engineers, Waldemar Lindgren's paper presented at the Pan-American Scientific Congress held at Washington, D. C., in January, 1916, is reprinted. Mr. Lindgren first described the general geology of North and South America, the eastern regions of which consist of sedimentary deposits undisturbed for ages. Erosion in places bared pre-Cambrian rocks. The western regions consist of high land, mountains, and plateau, forming the ranges that extend from Alaska to Tierra del Fuego. These were formed by the folding and uplift through the Cretaceous and early Tertiary ages, accompanied by lava flows. The gold and silver deposits can be divided into two classes according to these two geological conditions. In the middle and eastern parts of North America these ores are deep-seated, and are found in the exposed pre-Cambrian rocks in South Dakota, Ontario, and the southern Appalachian States. In South America similar occurrences are found in Venezuela, the Guianas, Brazil, and Uruguay. The western or Cordilleran deposits in the United States are found in the Rocky Mountains and Sierra Nevada; in South America in Colombia, Ecuador, Peru, Bolivia, and Chile, to the extreme south. The accompanying map shows the situation of deposits in the southern continent. Gold deposits in the northeast are mostly in the form of placers. Veins have been explored, the best instance being the Callao mine of Venezuela, which is said to have yielded $29,000,000 from 1865 to 1895. The primary veins from which the gravels were derived are contained in pre-Cambrian schists, diorites, diabase, granites, and granite porphyries. Excepting occurrences southeast of the Amazon delta, there is a barren interval until southern Brazil is reached, where the most important deposits are those in the State of Minas Geraes, where is the deepest gold mine in the world—the Morro Velho of the St. John del Rey company. The veins are of a deep-seated type, allied in places to pegmatite dikes. The next occurrence is in Uruguay, the mines being new Cuñapirú. The most southerly deposits of the older type appear in the Sierras of the Pampas in Argentina. In describing[1] the mineral resources of Uruguay, Rolf Marstran-

[1] *Min. Mag.*, June, 1916.

der says that it is seldom that anything is seen in the mining papers relating to that republic, and to most engineers the geological features and mineral resources are practically unknown. A real mining industry has never existed in Uruguay, nor does it exist now. Disadvantages may be ascribed to: (1) the heavy overburden preventing discovery of minerals even in places where conditions are favorable; (2) little interest in and small local knowledge of mining; (3) poor transportation facilities; and (4) lack of coal, oil, and water for power. The Government is now giving attention to aiding the industry. There are a number of abandoned gold-

Fig. 5.

copper and silver-lead mines. The Uruguay Consolidated Gold Mines is operating at Corrales, in the department of Rivera. Capital is wanted to re-open and develop other properties. The country lies between the southern Brazilian granites, metamorphic schists, and the eastern Argentine formations of Tertiary and Quaternary deposits, or pampas formation. The country is flat or slightly undulating and bare of forests. Mr. Lindgren stated that Colombia yields gold worth from $3,000,000 to $4,000-

000 per annum, which probably could be considerably increased. The deposits are mainly in the western and central ranges. The richest placers are along the Magdalena, Porce, Cauca, and Nechi rivers. On the last-mentioned the Oroville Dredging Co. has two dredges at work. Climate and transport have hindered development. Most of the lode mines are in five departments, those in Antioquia and Cauca being the most important. The lodes are closely related to the California type, generally quartz veins with free gold and the common sulphides. Ecuador apparently is not rich in precious-metal deposits. Nearly the whole gold output is from the old Zaruma mines near the boundary of Peru, and 53 miles inland. The veins are in fine-grained diorite. J. W. Mercer described[1] mining in Ecuador, saying that when only one mining enterprise is in operation, namely, the Zaruma, it was difficult to write on the subject. While the republic's minerals are almost undeveloped, there are many evidences of them. There are few roads and railroads. Owing to the climate and insects mine timbers soon decay. The immense uplift of the Andes through Ecuador has given a vast area for prospecting, but this is difficult of access on account of lack of roads and dense growth. Gold-bearing veins exist in many parts of the mountains. The Indians wash gold from many rivers. In the Zaruma district the rocks are mainly large flows of andesite, dacite, and rhyolite, lying on mica-schist. Extensive faulting is evident. The quartz veins are often 15 ft. wide. Ancient workings abound in large numbers. The ore milled is a mixture of quartz and calcite, with 10 per cent. by weight of sulphides. Treatment offers few difficulties. The native labor becomes efficient in a short time. Peru has relatively few gold deposits, some veins and some gravel in the southern part. The annual yield is seldom over $500,000, half being derived from the Cerro de Pasco copper mine, one-sixth from placers, and one-fourth from gold-quartz mines. On the other hand, Peru is the principal silver producer of South America, yielding nearly 10,000,000 oz. annually. Half of this metal is from Cerro de Pasco, the remainder from silver or gold-silver deposits. The many silver districts are in the western Cordillera and the output can be increased considerably. Peru is greatly different from Colombia from a geological standpoint. The majority of Peruvian deposits appear to be in close genetic connection with many small intrusive masses of deep-seated dioritic or monzonitic porphyries not connected with the flow rocks. Practically all the deposits are of the intermediate type, formed far below the surface. There is some mineralization around large intrusive masses or batholiths of granodioritic rocks. Bolivia produces little gold just now. Placers on the eastern slope of the Andes, east of Lake Titicaca, have yielded large

[1] *Min. Sci. Press*, **112**, 161 (1916).

quantities. South of this there are other deposits. Two veins are worked in the eastern range, both saddle-reefs enclosed in slates and sandstones. The ore is low-grade. It is well known that Bolivia has been an enormous silver producer, but at present the output is from 2,500,000 to 5,000,000 oz., a large part coming from the tin mines. The silver deposits are of the deep-seated type connected with intrusive rocks. As the silver veins of Cerro de Pasco in Peru changed into copper veins at depth, so the rich silver veins of Potosi, Bolivia, have been transformed into pyritic tin-bearing veins. Chile is noted for its nitrate and copper deposits, but so far the gold and silver deposits are of little account. Some gold-bearing veins are found in rhyolite, and some silver-gold in andesite. The latter peter out at depth. Gold-quartz veins connected with intrusives, such as granites and quartz-diorites, are numerous. The richest silver mines occur in Mesozoic limestone, intruded by or interbedded with various greenstones. The gangue is mainly calcite, while the rich ore contains antimonial and arsenical silver minerals. The southern half of Chile is remarkably poor in minerals. This is due to topographical and geological features. Some dredges have operated in Tierra del Fuego, yielding up to $600,000 yearly. Argentina produces little gold and silver. Pre-Cambrian mineralization of the Sierras of the Pampas is feeble. Prospects are rather abundant, but at few places has serious work been done. Considerable work has been done in the district on the head waters of the Neuquen River, where the gold-quartz veins are in granite of uncertain age. The ore apparently is of low tenor. Few data are available concerning the placers.

In Honduras, Central America, the New York & Honduras Rosario Mining Co. continues its profitable operations. The average monthly yields of the past 2 years were as follows:

	Tons of Ore.	Oz. of Gold.	Oz. of Silver.	Profit.
1916	10,565	1280	150,600	$125,000
1915	9,815	1267	145,659	97,125

This property is controlled from New York. It is in mountainous country.

Brazil.—Among the many descriptions[1] of mining operations in South America by B. LeRoy Miller and J. T. Singewald, Jr., that[2] on the gold mines of Brazil was of interest to readers of this chapter. When the Portuguese opened the country placers received first attention, but are now of little importance. Generally speaking, gold mining has received little development in this republic. Two rather remarkable gold mines are being profitably operated, the Morro Velho of the St. John del Rey company, and the Passagem of the Ouro Preto company. Both are in the State of

[1] *Eng. Min. Jour.*, **101** and **102** (1916).
[2] *Loc. cit.*, **102**, p. 207.

Minas Geraes. The Morro Velho produces monthly £39,000 ($187,000) from 16,100 tons of ore. In its last financial year the company's profit was $700,000. It is the oldest gold mine in the Western Hemisphere, and the deepest in the world, namely, 5826 ft. A shaft is to be sunk 1200 ft. below this point. Ventilation is one of the chief problems, but the temperature is being reduced somewhat by fans and connecting workings. The ore, a quartz-siderite-dolomite-calcite mixture, contains arsenopyrite, pyrite, and pyrrhotite, most of the gold being in the arsenopyrite. After table concentration the ore is cyanided. The Passagem mine is also an old one, but has good prospects for the future. As in the Morro Velho mine, the gold here occurs in the arsenopyrite, and some excellent metallurgical work has been done.

Chile.—In covering[1] the mineral industry of Chile, Lester W. Strauss says that gold mining is an unimportant industry, in which vein mining contributes less than placer work. Less than 3 per cent. of the gold is in the copper products. Silver mining continues to be a declining industry. The annual output is over 1,000,000 oz.

Colombia.—Mining possibilities in Colombia, South America, were discussed[2] by M. W. Alderson, who examined some properties in the republic. He found some things there similar to those going on in the United States, such as people holding worthless claims, champagne equipments on beer mines, difficult transportation, and waste of money generally. Good placer ground remains untouched in parts. The skill of the natives was described, showing that they are past masters in the art of washing gravel for gold. Capital and technical management are necessary for wholesale mining of the deposits. The results of the Pato Mines, Limited, were covered. This company has two dredges, which are yielding good profits. Hydraulic elevators operated on the Porce by the McGuire brothers have been a success; but suitable ground and pressure are not often available for this type of machine.

Peru.—Peru, which produces 64 per cent. of the silver of South America, was described[3] in a general way by H. E. West, more especially the silver deposits, transportation, and the people.

Gold and Silver Ore Treatment in 1916

A perusal of the leading technical journals and society publications shows that although there was a distinct falling off in the number of papers prepared during 1916, yet there were more than one would suppose, and generally they were of high order. Where once the journals devoted

[1] *Min. Sci. Press,* **112,** 475 (1916).
[2] *Min. Eng. World,* **44,** 947, 1076, 1169; **45,** 51, 367 (1916).
[3] *Min. Sci. Press,* **112,** 704 (1916).

much space to cyanidation, they now strive to secure as much on flotation as possible, this not meaning that articles on the former process are not desired. As an instance of this we may consider the American Institute of Mining Engineers. During the past year it issued 12 bulletins, totaling 2276 pages. Of these, 103 pages were occupied by papers on cyanidation, and 205 pages on flotation, or exactly double. This shows the trend of thought and investigation among many of the Institute's nearly 6000 members, representative of all branches of mining and metallurgy. At the same time, it must be remembered that many members do not contribute to the Society's transactions, but prepare papers for the technical press.

As will be seen from the following abstracts, there has been much controversy over the most suitable reduction machinery, and it would seem that the rotary type of mill is gaining favor at the expense of stamps. Cyanide solutions have come in for investigation, also settlement of pulp. The continuous decantation system is expanding. Melting of precipitate and bullion-refining methods improved. The flotation of gold and silver ores is gaining ground, and in 1917 the tonnage so treated may be a large increase, but metallurgists are going carefully and slowly in this new treatment. During the year there seemed to be an increase in the better recovery from such as gold-tungsten, gold-antimony, and gold-copper ores. In the first, work was done in such scattered points as the South Island of New Zealand and Idaho; in the second, Rhodesia and Nova Scotia; and in the third, Goldfield and Korea. In the last-named country the Seoul company's Soctarie deposit contains copper, tungsten and gold, a troublesome mixture.

The cyanide (salts) situation during 1916 became serious for small operators and new plants. The plant of the Roessler & Hasslacher Chemical Co. at Perth Amboy was run at full capacity, and only old customers could be supplied. This firm was not disposed to enlarge the plant, probably looking ahead when cheap cyanide would again come from Germany. The British Government continued its embargo on exports of salts excepting to the mines in Africa, Australia, Canada, and India, although the Cyanide Plant Supply Co. of London advertised that it could supply its old customers in America. Mexican mines were continually short of cyanide, otherwise they would have worked full time, in spite of the revolution; that is, in certain districts, such as Pachuca, El Oro, and in Jalisco. The upshot of the shortage was that cyanide rose to between 70 and 80 cts. per lb., where it remained during December. With the beginning of 1916 the Roessler & Hasslacher Chemical Co. changed the designations of its various grades of cyanide, basing them on sodium cyanide content. When these grades now on the market superseded potassium cyanide (KCN), the grades of sodium cyanide (NaCN) were designated by their equivalents in potassium cyanide, in order to show their comparative strengths. Potassium cyanide, 95 to 96 per cent. contains 38 per cent. cyanogen. Thus sodium cyanide containing 51 to 52 per cent. cyanogen was designated 129 per cent. that being its equivalent in potassium cyanide. Owing to its lower cost, sodium cyanide has now entirely replaced potassium cyanide in the treatment of gold and silver with equal, if not better, results. The composition of the salts is not changed. The lower cost of transportation is also an element of saving, because of the greater cyanogen content of pure sodium cyanide. Sodium cyanide (129 per cent.), 51 to 52 per cent. cyanogen-content, is now designated 96 to 98 per cent.

Zinc dust, used as a precipitant, remained at 30 cts. per lb. for several months, then dropped to 20 cts. where it holds steady. Fluctuations in spelter did not affect this commodity to any extent. The supply is not large (2400 tons domestic production in 1916 and 900 tons imported) and is mostly sold ahead. The use of the dust did not expand much, presumably because of the then uncertainty of the supply of zinc dust, although all new plants installed the method involving the use of pulverulent zinc. In this connection the advent of a new pulverulent precipitant known as Merrillite, is noted. Materially increased efficiency is claimed for this new precipitant. Donald F. Irvin discussed[1] zinc dust and zinc thread, the latter being used generally as it is a question of capital outlay. Aluminium dust, another precipitant, used at Cobalt, Ontario, was up to 90 cts. per lb. and at the Nipissing mill sodium sulphide was substituted. The precipitate, silver sulphide, is de-sulphurized by aluminium ingots in a caustic soda solution before being reduced to bullion. The manufacture of aluminium dust is by several methods,[2] one being where air is forced into the molten metal and the granules formed powdered in a ball mill. During this operation, according to G. H. Clevenger, gas is formed that frequently leads to explosions when enough heat or frictional electricity is generated. Good aluminium dust contains 92 per cent. of metal, 6 per cent. of oxide, and 1.3 per cent. silica.

In reviewing gold and silver metallurgy in 1916, an editorial in *Metallurgical and Chemical Engineering*[3] says:

> The gold metallurgist has given but divided attention to metallurgical progress during the year. He has been actively occupied with the problems arising from the upward trend in cost of the supplies required for producing his finished material, which, almost alone among commodities, has not appreciated in value. Prosperity has passed him by. He is the mourner at the feast. Such unsettled market condi-

[1] *Min. Sci. Press*, **112**, 115 (1916).
[2] *Min. Sci. Press*, **112**, 118 (1916).
[3] Page 5, Jan. 1.

tions, though responsible for many present inconveniences, hold some promise for the future, through the development of American sources of supply. Thus cyanide of American manufacture has entirely replaced the German product, and it may be said that in quality and uniformity it is equal to the best heretofore imported. Potassium cyanide has quite disappeared from the market, without ill effect on the output of American mines. Incidentally, we note with satisfaction that the manufacturers have ceased to refer their analyses to the potassium cyanide standard, and are quoting the content of sodium cyanide—certainly the only rational classification. If operators will follow this example and finally discontinue reference to "128 per cent. cyanide" and kindred absurdities, the cause of precision, at least, will have benefited. Silesian zinc dust, formerly the best material available, has been unobtainable since the early months of the war, so that operators have now 2 years' experience with the American dust. This, at first greatly inferior, has been improved until from at least one source is obtained a dust even superior to the best Silesian grade. The advance in price has stimulated investigations directed to the improvement of precipitation methods and of precipitants, and it is probable that interesting developments in this branch of cyanidation may be expected within the current year (1917). In this connection the recently reported preparation of electrolytic zinc dust is of interest. Another step in conservation, due to the impelling force of rising prices, may be noted in recent practice at the Homestake, where certain classes of precipitate are retorted for the recovery of the quicksilver content, prior to smelting for gold and silver.

The silver metallurgist passed, in the meanwhile, through much the same experiences. At the nadir of his fortunes a year ago, he has been relieved during the past 8 months by a strong market for his metal, so that for him the burden of war prices has been lightened. The Cobalt district witnessed tremendous appreciation in the cost of aluminium dust and of sodium hydrate, both of which are largely used in the processes more or less peculiar to that district. Perhaps the most striking feature of recent work there is the increasing attention being given to the salvage of minor metals in the ore.

Steady progress has been recorded in the application of flotation to the metallurgy of gold and silver. At Goldfield and in the San Juan, plants are in successful operation; at Cripple Creek and Cobalt the process is receiving attention as a means for the beneficiation of difficult ores. A consideration of the ores under treatment in these districts—copper-bearing sulphides, mixed sulphides of lead, zinc and iron, tellurides, and arsenides—indicates clearly the field best suited for its application. It is our impression that the year has done much to establish the practical limitations to its usefulness.

Ores relatively amenable to cyanidation, not requiring roasting or other preparatory treatments and containing no metals of secondary but commercial value, offer little opportunity for flotation to displace established methods. When in such circumstances the newer process is favored, it may be presumed that because of small ore reserves or limited capital unusual stress has been placed on the smaller initial cost of plant. This, one of the strong claims of flotation to consideration, is offset by the fact that it is not a complete process, but must depend on smelting or other subsequent treatment for the final recovery of its metals in marketable form. In the development of the flotation process the equipment of the cyanide operator has been drawn on freely, and several devices have become standard equipment in the flotation mill.

New mill construction indicates that the gold-mining industry has generally accepted the crushing methods of modern copper mills. The Alaska-Gastineau has scored a sound technical success in its milling operations, however its position marketwise has been affected by the disappointing developments in the mine. The first successful application of the ball-mill to gold ores was made, we believe, at the Vipond. Now we hear that these mills are to be installed at the Dome, displacing stamps of comparatively recent design. This advance seems reasonable, and we look for its continuance. Too much stress has always been placed on the supposed simplicity of the stamp. The past generation of engineers often spoke of "muscular metallurgy." The phrase was probably coined by a stamp-mill operator. As an amalgamating device, the stamp is preëminent, but complete recovery by this means is seldom attempted in these days, and it is probably sufficient thus to care for the coarser particles of gold. It is to be regretted that published data of ball-mill performance have generally failed to take account of the accessory crushing machines which must both precede and follow it in the flow sheet if it is to duplicate the product of the stamp. A competitor of the ball-mill is a machine that carries a charge of steel rods instead of balls, and is worth study.

In mill design other than crushing, the trend to counter-current decantation has continued, at the expense, in great measure, of the basket types of filter. Thickeners of the tray type are proving valuable. At the Liberty Bell, Colo., crucible smelting of precipitate, with preliminary sintering, has been put on a rational basis.

In his annual review in the *Engineering and Mining Journal* Herbert A. Megraw says:[1]

While there were no notable developments in the metallurgy of either gold or silver during 1916, there were nevertheless many mills operated at their highest capacity, and there was a steady development in the perfection of metallurgical methods already known. Perhaps the most instructive and interesting feature has been the application of the flotation process to both gold and silver metallurgy. Although this was not considered possible a short time ago, a few recent installations have shown that highly successful results have followed the adoption of the process into this, for it, new field. As an example it may be pointed out that the Goldfield Consolidated mill has installed a large number of Callow cells designed to replace eventually the cyanide treatment. At this mill it is considered that flotation equipment treating 1000 tons daily may save up to $400,000 annually, without taking into account the higher extraction that may be secured. Another instance of the same thing was noted in the *Journal* of July 1, 1916, in which Ralph W. Smith described at length the treatment of an ore containing gold in addition to lead, silver and zinc, using the flotation process and extracting the gold by it successfully. In the course of this article Mr. Smith says: "One of the first things noted in the operation of the flotation machine was the fact that the free gold floated. . . . Assays showed that much cleaner gold tailings were being made than by any other machine in the mill. The percentage saving of gold reached about 85 per cent." While many cyanide plants have continued operating in the usual way, some of them have been partly, and a few wholly, changed over into flotation plants. An instance of this is the Oneida Stag mill, in Colorado, which was entirely changed over from cyanide to flotation, with good results. While most of the mills making use of flotation have been those in which base metals are treated, still, in a number of cases the precious metals have been recovered as a sort of by-product, such as the silver recovered in the concentrates of the mills in the Cœur d'Alene district of Idaho, and the gold in the copper recovered in some of the Montana mines. It seems, however, that now flotation is likely to be

[1] *Eng. Min. Jour.*, **103,** 57 (1917).

used on purely precious-metal ores. During the year it has been noted that flotation experiments have been tried at the Santa Gertrudis mill, at Pachuca, Mexico, and the experimenter expresses his opinion of the possibility of a part of the ore, at least, being susceptible of flotation treatment with good results.

Whatever changes are noticeable in gold and silver metallurgy have begun, apparently, in the grinding department. The development of the newer machines has continued, and many of the plants have been making use of the Hardinge mill, the quick-discharge tube mill, the Marcy mill, and also the Marathon mill. The last-named has been the subject of considerable discussion during the year and is worth studying. Another feature of ore reduction has been the use of iron-compound balls, or pebbles, replacing the flint pebbles in the tube mills. This has not been at all unusual, and efforts have been made to develop a highly resistant iron compound which would give better wear than flint pebbles and reduce the cost of tube-mill grinding. Some success along these lines has been attained, and it is hoped that a satisfactory pebble may be developed soon. Trials have been made on an extensive scale in the Cobalt mills, and also at the Hollinger, at Timmins, Ontario.

It may be noted that a good many of the Cobalt silver mills have been trying flotation with more or less success, among the successful ones being the Buffalo. At the Nipissing, Dominion Reduction Co., and several others work is still in the experimental stage. Metallurgy in general has continued in about the usual way in the Cobalt district, although some changes have had to be made in view of the scarcity of supplies of certain kinds. At the Nipissing, for example, aluminum and aluminum dust have been so scarce that new methods of precipitation have had to be worked out, and it is generally understood that sodium sulphide had been used, although the company has given no official announcement of such a change.

In the Tonopah district there has been little change, although in common with most districts, the principal companies have been making experiments with flotation. At the Tonopah-Belmont mill, in addition to flotation experiments, the only changes of note have been the adoption of a new type of filter-leaf, which has been productive of good results by lowering the dissolved losses nearly one-half. The Belmont tube-mill liners that were installed in previous years have also proved satisfactory, having materially reduced the cost of grinding. At the Belmont mill, at Millers, Nev., operations were continued, the mill having been re-modeled into a continuous-decantation plant, at a cost of about $25,000. This amount has been entirely refunded by the profits of the plant during its operation under the new system. All the Nevada precious-metal mills have continued operations in about the usual way throughout the year, although there have been minor changes at some of them. The Churchill Milling Co., operating on ores of the Nevada Wonder mine, at Wonder, has been somewhat changed so as to increase its capacity. Metallurgically speaking, however, there has been no important alteration.

The Rochester and Nevada Packard mills at Rochester are operating in the usual way. Cyaniding is still the principal process in these districts, although flotation is being experimented with. At the present time no one seems to be up-to-date unless he is either using flotation or experimenting with it, and there seems to be little doubt that many companies are going to be able to effect large economics by its use.

Among the interesting new installations may be mentioned that of the Big Pine Consolidated Mining Co., which has completed an interesting cyanide plant at its mine 12 miles south of Prescott, Ariz. At this mill the ore is crushed in the usual way with Blake crushers and rolls. The metallurgy is by the counter-current decantation system, which, however, contains some original features, but since this installation was described in the *Journal* of Dec. 16, 1916, it will not be worth while to repeat it here. At Oatman, Ariz., the new mill of United Eastern will use cyanidation in the usual way.

Mexico continues to be a total blank so far as mining and metallurgy are concerned. It is true that some of the mills are running and producing bullion, but production is nowhere near normal, and operations can not be carried on in the proper manner. Transportation difficulties and the possibility of brigandage make calm progress out of the question, and there will have to be a considerable wait before proper results can be expected there.

One of the interesting developments in precious-metal metallurgy is found at the Dome mill, South Porcupine, Ontario. It will be remembered that this mill was built originally as an all-slime plant, using stamps, crushing in water, amalgamating on plates, and then regrinding, thickening, adding cyanide solution and agitating in Pachuca tanks. The mill operated in this way for some time, and it was later changed into a sand-and-slime treatment plant by the addition of sand tanks, thus eliminating a large part of the regrinding and increasing the mill capacity. Steps have now been taken, however, to do away with the stamps altogether, increase the sand-treating installation and thus reduce cost and increase the mill capacity again. Hardinge mills are being used to replace the stamps, and it is noted that one of these mills, size 8 ft. diam. by 30 in., may be installed in the space occupied by the 10-stamp installation, the mill handling as much, under certain conditions, as 400 tons per day. Regrinding tube mills, 22 by 5 ft., are being added, and many other improvements made. The sand- and slime-handling capacity has been much increased, and another 90-frame Merrill slime press has been installed. The new constructions and developments at the Dome mine have cost up to the present time about $500,000, and another $75,000 will probably see the completion of those changes already planned.

Amalgamation, as a major metallurgical process, has been retired more and more into the background during the last few years, but it has not altogether disappeared and it seems likely that, as an auxiliary, it will continue to be practised more or less extensively. It is still used in California, Colorado, some parts of Canada and in South Africa. The Rand mines have used the system much as in former years, and these properties have been subjected to heavy pressure for gold production during the year. In common with most of the gold mines of the world, production has been pushed to the maximum, because the metal has been required to pay debts.

The question of combining the cyanide and flotation processes in the beneficiation of gold and silver ores has had some study during the year, but in general, operating companies have been so busy in other ways that no conclusion has been reached. The possibility of cyaniding flotation concentrates is a detail that seems to have some importance in this connection. Of course, where silver or gold ores are subjected to flotation, the natural subsequent step is to ship the concentrates to a smelting plant, but in isolated districts where such a course is not economical, it might pay to cyanide them on the spot.

It has been suggested that the oil remaining in concentrates of this kind might prove to be a consumer of cyanide, and in fact some operators have found it so. Others, however, claim to have been able to cyanide such material without undue loss of the chemical and without especially treating the concentrates. If treatment should be required to eliminate the oil, there is open the choice between roasting, washing with hot water and the final one of attempting to saponify the residual oil. Sometimes the last course is possible, but it will probably not become usual practice. The first may often be used, since it accomplishes two desirable things at the same time, but it may cause some trouble by leaving a mischievous carbon deposit. Hot-water washing is practicable in a good many instances.

Taking it all in all, the review of the metallurgy of gold and silver for the year leads to the conclusion that while there have been no great advances in actual ore-treatment methods, developments have been kept up continuously and a large amount of new construction has been undertaken. The feature of flotation has been interesting, since it has been tried experimentally by nearly all the companies treating any kind of ore, and it may be expected that within the next few years surprising installations will be forthcoming, particularly at mills treating silver-sulphide ores principally.

In his review of cyaniding in 1916, P. M. McHugh,[1] general manager of the Dorr company of Denver stated that there has been little advancement in cyanidation during the past year. Most of the plants built have been along standard practice. One or two plants have, however, increased their efficiency by changing to the all-slime treatment and several new continuous counter-current decantation plants have been erected.

A year ago many operators believed that flotation would take the place of cyanidation, but this has only proved the case on certain classes of ore. It is really difficult, even at this time, to determine just what influence flotation will have on the cyanide process, although it would seem as if plants treating ores carrying a high proportion of sulphides, or ores of unoxidized character, may be greatly benefited by the use of flotation. This is evidenced by the results obtained by the Argo Reduction & Ore Purchasing Co., as well as others that have changed from cyanidation to flotation with most gratifying results. These conditions, however, were just reversed at a well-known plant (Portland) in the Cripple Creek district, where a large flotation plant was planned. It was found in treatment that the ore was to a great extent oxidized, and could not be handled successfully by flotation, the result being that the company is now erecting a 1000-ton plant to treat the ore by cyanidation. The first experiments that were apparently successful were conducted on sulphide ores, but when flotation was attempted on ores containing both oxide and sulphide minerals, it was demonstrated that conditions favorable to the flotation of the sulphides would not give satisfactory results on the oxide portion, and the reverse.

In districts such as Cobalt, where flotation would be used instead of cyanidation, the problem of refining the recovered concentrate has proved serious. Concentrates from this district generally contain cobalt, arsenic, and nickel, thus making the refining cost high.

The matter of flotation testing is an important feature, as it is not always possible to show results in practice corresponding to flotation experiments. There have been several marked examples of this difficulty, but with further development of flotation it may be possible to show what causes this divergence. From cyanide tests it is possible to tell

[1] *Salt Lake Min. Rev.*, Jan. 15, 1917.

closely the results that may be obtained in mill practice. There are many problems to be considered in the use of the flotation process on gold and silver ores, such as plants that are located at some distance from the railroad, thereby making it necessary to ship concentrate. In the case of cyanide plants this problem is simplified, in that they can ship the bullion direct. It is unlikely that flotation will replace cyanidation on gold and silver ores where there is not sufficient base metal to produce an increased revenue from the concentrate, except where the ore may be of a refractory nature, and not amenable to cyanide treatment. The cost of bullion recovered by flotation is often greater than the cost of bullion recovered by the cyanide process, and at one plant it was estimated that an additional extraction of 5 per cent. was required on the ore when flotation was used, to balance the cost of cyanidation. Many of the methods of handling pulp in the flotation process have been adopted from cyanide practice, such as crushing in closed circuit with classifiers, thickening the pulp before flotation, and thickening flotation concentrate by means of Dorr thickeners. On the other hand, some of the cyanide plants installed during the past year have been adopting ball-mill crushing, which is used largely in flotation mills, in place of stamps and other grinding mediums. Development during the coming year will doubtless demonstrate more clearly just how far it is possible for flotation to replace cyanidation.

During the past year the cost of supplies has had a serious effect on the cost of operating cyanide plants, and at the present time there is a great scarcity of cyanide, and the ready supply available is selling at an excessive figure (80 cts. to $2), which will require the closer attention of the operator to mechanical losses of cyanide in the process. Careful attention to these losses will mean a greater recovery in the dissolved value losses also.

The development of the Dorr tray thickener, which will greatly reduce the size of thickeners required in cyanide plants, will prove a valuable adjunct in the initial cost in the future.

A development that has been going on during the past 2 years has shown the advisability on a great many ores of making a change of solution during agitation, and the extraction has been materially benefited.

Sampling

Sampling of ore, whether it be at a mine, mill, or custom reduction works, is of great importance, much of it being done on an unscientific basis, and the publication of the U. S. Bureau of Mines *Technical Paper* 86, entitled "Ore-Sampling Conditions in the West," by T. R. Wood-bridge, was timely. In California, Colorado, Montana, Nevada, Utah, and Washington, 48 plants were visited, sampling ores of gold, silver, lead, copper, and zinc. The subject dealt with weighing, coning and quartering, shoveling, and mechanical samplers, and gave 55 flow sheets of sampling systems.

Chemistry in Cyanidation

Cyanide solutions lose their strength during the treatment of gold and silver ores by chemical and mechanical processes, according to G. H. Clevenger and Harry Morgan, who wrote one of the most informing papers[1] of the year, entitled, "Atmospheric Decomposition of Cyanide Solutions." The following is a summary, with comments, of their results:

Millmen are familiar with the odor of hydrocyanic acid gas in a cyanide plant, particularly in damp weather, but few have troubled to investigate the cause of it. By the dissolving of precious metals in cyanide solution and their subsequent precipitation, most of the cyanide is lost, that is, a weak solution is made up to working strength by adding cyanide salt, but during the cycle of operations the solution returns to its original weak point, therefore the salt added is consumed. Chemical and mechanical causes account for losses of cyanide, the principal ones being reactions with the ore, atmospheric decomposition, waste in residue, and leakage from tanks. These losses are not the same in any two mills, even on similar ores. Cyanicides in ore and water are always present, and usually they can be checked, but not without constant attention. Mechanical losses should be reduced to a minimum without much trouble. The average metallurgist knows that air plays an important part in cyanidation, also that it causes decomposition of the solution, but he has been content to assume that this was unavoidable. And his conclusion is not far wrong. In 1909 Mr. Clevenger observed that when a plant was treating below its capacity, consumption of cyanide per ton of ore was greater than when working at full capacity, although the quantity of solution in circulation was similar for both tonnages, giving the air equal scope for action. Laboratory tests made at a plant in Central America showed that after 216 hr. exposure to the mill atmosphere only a trace of KCN remained. Several kinds of cyanide with different solutions were tried, confirming previous tests, although there was less decomposition in the mill-solutions than in those from fresh cyanide to which no protective alkali had been added. Light has practically no effect on the decomposition of solutions, as was proved by exposure for 192 hr. in light and dark stoppered bottles. In 1912, A. J. Clark made a similar test at the Homestake, showing substantially the same decomposition. Julian and Smart, Thorp, Clennell, and Watt have

[1] *Min. Sci. Press*, **113**, 413 (1916).

discussed atmospheric action on cyanide in their books. While studying these reactions, Messrs. Clevenger and Morgan found it necessary to determine cyanide, cyanate, hydrate, carbonate, ammonia, and formate in cyanide solutions. This work necessitated careful research. Next they exposed solutions of a particular strength to the air in 5½-in. beakers. In two series of tests when no alkali was added, a steady loss of cyanide was observed; but where alkalinity was kept constant the rate of decomposition was lowered. A study was made of the gaseous products of atmospheric decomposition of solutions, with the discovery that most of the reaction involves the formation of HCN. Other products are an alkaline carbonate and ammonia. In addition to atmospheric action, there is the decomposition known as hydrolysis, having the equation

$$KCN + H_2O = KOH + HCN.$$

This proceeds until equilibrium is established for the particular concentration of cyanide in solution. A mill-solution that contains no protective alkalinity, may lose some of the HCN through normal hydrolysis, but if sufficient air be brought into contact with the solution a large part of the cyanide may be lost through progressive hydrolysis. Hydrolysis may be defined as the chemical decomposition of a compound that ensues when the group H_2O is absorbed by it, causing the formation of new compounds. Cyanide plants that operate with a low alkalinity run the risk of losing cyanide owing to the accumulation of the soluble alkaline carbonate, K_2CO_3, which does not afford protection against the CO_2 of the air when the real protective alkalinity (lime) has disappeared.

In another part of their paper, the authors discuss investigations on the Rand during 1915. In treating 25,701,954 tons of ore, there was consumed an average of 0.4 lb. per ton. A number of tests on typical sand and slime showed that the loss of cyanide, due to the escape of HCN as gas into the air, was from 44.7 to 49.5 per cent. Loose or incomplete covering on sump-solution tanks did not suffice to prevent loss of alkali or cyanide. In weak solutions there is no loss of HCN as total cyanide, and but little loss as free cyanide, so long as a protective alkali is present. When the protective alkalinity is below 0.01 per cent. NaOH, the loss of HCN as free and total cyanide becomes serious. The presence of zinc considerably decreases the loss of HCN by hydrolysis. Another investigation covered the exposure of working solutions to the atmosphere under varying conditions. While transferring solutions from slime treatment vats at one plant, as much as 0.14 lb. of sodium cyanide per ton of slime disappeared by evaporation of HCN. It was concluded that the loss is greater in pure synthetic solutions, when making tests, even with added alkali, than is the case with ordinary working solutions, and a heavy loss is shown in the presence of little or no protective alkali, when determined with additions of ferro-cyanide. By fitting tight covers to treatment-vats and solution-tanks a saving of 0.09 lb. per ton of ore might be effected. Regarding hydrolysis, it was ascertained that simple solutions decompose by this action; higher temperatures accelerate this decomposition; the alkali formed as a product of hydrolytic action has little or no protective effect on the remaining cyanide, so that hydrolysis proceeds until all the cyanide is destroyed; and that the protection afforded by adding an excess of caustic alkali is only of temporary value. Messrs. Clevenger and Morgan attacked the problem in the same general way as the African metallurgists, but completed most of their tests before the latter began. Generally our authors agree with them, but are not in accord concerning the protective alkali. Whether atmospheric decomposition of cyanide is worth the study of mill operators is answered by concluding that: (1) it may become a serious factor with solutions containing little or no protective alkalinity; (2) the cyanide lost through reactions with oxygen can not be economically recovered; and (3) the most effective method of preventing decomposition is to maintain a sufficiently high concentration of alkaline hydroxides in the solution.

By means of a chart, H. H. Howry shows[1] a new method of expressing protective alkalinity, which he considers has some points that make it preferable to the old way of giving so many pounds of lime per ton of cyanide solution. The protective alkalinity is expressed as a percentage value.

Lead salts, alkalinity, soluble sulphides, and solvent power of cyanide for gold were the chemical problems investigated by H. R. Edmands[2] during experimental work on leaching roasted gold ore. Special attention was given to solutions foul with soluble sulphides, and to solutions in which the sulphur was mainly converted into thio-cyanates and thio-sulphates, and none was present as sulphide. The general conclusion regarding lead salts is that their use in silver-ore treatment is decidedly beneficial, and also to a lesser extent in gold ore, provided the correct quantity is added. No specific rule is given for determining the right amount, nor is any reason advanced as to why an excess may prove injurious. By adding lead acetate to roasted ore, and omitting lime, the best extractions were made, at a cost, however, of greater cyanide consumption. No soluble sulphides were present either before or after treatment. When roasted ore was agitated with solution foul with soluble sulphides, it appeared that when the solution contains little or no pro-

[1] *Eng. Min. Jour.*, **102,** 139 (1916).
[2] *Month. Jour. Chamber of Mines,* Kalgoorlie, Western Australia.

tective alkali, the use of acetate in just sufficient quantity to precipitate soluble sulphides is beneficial, but may be injurious in the presence of much lime, especially if the acetate be in excess. The effect of adding acetate to solutions containing soluble sulphides is that if the precipitated sulphide be removed by filtration, a considerable increase in solvent activity ensues; but the presence of lead sulphide renders solutions carrying any protective alkalinity almost incapable of dissolving gold, which power is only imperfectly restored by neutralizing the protective alkalinity.

A. F. Smith, who has discussed[1] the alkalinity of cyanide solutions, also[2] dealt with the heating of solutions. He erroneously concludes that nothing is gained by heating solutions above the temperature of normal summer weather. Results at Tonopah contradict this assertion.

J. E. Clennell's "Recent Advances in the Manufacture of Cyanogen Compounds"[3] may be termed a highly chemical paper. The conversion of cyanamides into cyanides is the part of interest to cyaniders at present. Fusion and wet methods have been proposed. The best known is that of Erlwein and Frank, by which crude calcium cyanamide is converted into a product containing the equivalent of 25 to 30 per cent. KCN by fusing with carbon and common salt. Its market name is "surrogat," and per unit of cyanogen contained appears to be as effective as sodium cyanide for dissolving the precious metals. Before using it requires a little preliminary treatment.

J. E. Clennell gave[4] methods for estimating the metallic aluminium in aluminium dust. This estimation is necessary as a measure of its utility as a precipitant. Chemical accuracy in such an estimation is difficult to attain, but satisfactory comparative methods may be used. The gasometric process consists in dissolving a known weight of the dust in dilute hydrochloric acid, then collecting and measuring the hydrogen evolved. Theoretically it is simple, but in practice complicated by various considerations. Zinc contained also evolved hydrogen. A volumetric method is used, wherein aluminium dust is heated with ferric sulphate and sulphuric acid.

The commercial application of the cyanide process to the treatment of gold and silver ores was due to J. S. MacArthur and R. W. Forrest of Glasgow, Scotland. The early history of experiments has never been published in collected form, so the article[5] by MacArthur himself is of unusual interest. One of the rules in testing was to produce the gold recovered. The first cyanide plant, designed as such, was for the Crown

[1] *Min. Sci. Press*, **112**, 828 (1916).
[2] *Min. Sci. Press*, **112**, 889 (1916).
[3] *Met. Chem. Eng.*, **12**, 756 (1916).
[4] *Eng. Min. Jour.*, **101**, 813 (1916).
[5] *Min. Sci. Press*, **112**, 851 (1916).

mines in New Zealand. The chemistry of the process is discussed by Mr. MacArthur.

When crushed with ore, carbonaceous shale gives tiouble in cyanide plants by causing premature precipitation of the gold. Paul W. Avery details[1] some work done at El Oro, Mexico. The San Carlos ore at Esperanza carries 50 per cent. of a black carbonaceous shale, which, when crushed, floated on the pulp like oil. The film of carbon must have great precipitating power, as it assays high, principally in gold. Samples of shale from the vein possessed variable precipitative efficiencies. Cyanide would not dissolve the metal adsorbed by the shale. The shale itself carried little gold or silver. The problem resolved itself into a chemical one, and was solved by crushing the ore in water, agitating the pulp in a Pachuca tank in the presence of an acid-salt (commercial bisulphate of soda). This neutralized the precipitative power of the shale. The after-effects from using such a salt must be watched and counteracted in subsequent cyanidation.

H. Fischer followed this with an article[2] entitled "Effect of Black Slate on Cyanidation." While observing the cyaniding of concentrate on the Mother Lode of California, it was remarkable that results closely paralleled those of Mr. Avery. Summarizing, Mr. Fischer says that concentration, classification, and screening play important parts in the elimination of graphite. Mechanical methods will remove the slate, while the Na_2CO_3 is expected to take care of the arsenic in the mineral. The original ore is not amenable to cyanide, but responds readily to flotation.

Crushing

Advocates for the new school of crushing ore have for years heralded the doom of the stamp as part of the flow sheet of a mill, and yet, although we note the use of ball mills and rolls for gold ore in Alaska, Ontario, and other places, the gravity stamp continues its good work and finds a place in new plants. In one center, Porcupine, we find stamps and ball mills, respectively, in two plants, the latter crusher replacing the former in one. In discussing[3] stamps and competitive machinery, H. C. Cutler quotes an editorial[4] in which it is argued that if gold-mill operators are prepared to abandon the use of the stamp as an amalgamating device, and will send the stamp-mill pulp direct to tube mills, passing their discharge over plates before it goes to the cyanide-plant, the question may be raised whether it is necessary to retain stamps for preliminary crushing of the tube-mill feed. The tube-mill action frees gold from its

[1] *Min. Sci. Press*, **112,** 514 (1916).
[2] *Min. Sci. Press*, **112,** 743 (1916).
[3] *Min. Sci. Press*, **112,** 204 (1916).
[4] *Min. Sci. Press*, **109,** 511 (1914)

adhering gangue quite satisfactorily, and it would seem that the crushing of the tube-mill feed should be done by the most efficient machine, regardless of its crushing action. The new mill of the Alaska Gastineau company uses rolls and tube mills, the former being used in the copper mills. It is difficult to see why stamps are used for crushing through 4-mesh, as is done on the Rand, for instance, where 10,000 stamps are working. One millman considers stamps as flexible; that is, screens are easily changed, height of discharge altered, and fineness of product easily varied. A stamp is a small unit, fool-proof, simple in design and operation, and easy to transport; repairs are easy; it will crush any class of ore; and is advantageous in amalgamation.

In many places these advantages would hold good, but for large plants there are other more efficient machines. The whole problem is to reduce the product of the coarse-crushing plant, say, a maximum of 1½ in., to the fineness best suited for metallurgical treatment. Results at some of the large copper mills, especially the Inspiration Consolidated, prove that one-stage reduction in a ball mill of the Marcy type is cheaper than multiple-stage reduction; therefore it is logical that for an all-sliming plant for gold ore, ball mills in closed circuit with classifiers should suffice, eliminating stamps, tube mills, Chilean mills, rolls, etc. Where an all-slime product is desired, the tube-mill feed should be finer than 8-mesh, so that, disregarding for the moment the one-stage reduction machine, the problem resolves itself into reducing 1½-in. material to at least 8-mesh as cheaply as possible. With the exception of the ball mill, the Huntington mill, roller mill, Chilean mill, and centrifugal crushers have been tested in competition with stamps for one-stage reduction, the consensus of opinion being that the stamp is preferable. (J. W. Hutchinson of the Goldfield Consolidated states that: (1) ore may be reduced to 4-mesh in the stamp battery more economically than to 12-mesh; (2) for the reduction of particles to 16-mesh, where all-slime is required, stamps followed by Chilean mills are more efficient than stamps alone; and (3) ore may be reduced to 200-mesh in the tube mill cheaper when the mill is fed with 16-mesh than with 4-mesh.) Can this reduction be done by any other set of machines than stamps and Chilean mills? Rolls are not adapted to all classes of ore as are stamps. Mr. Cutler thinks that one Symons disc-crusher would do the work of the 100 stamps at Goldfield. The adoption of ball mills by the Inspiration (crushing a total of 18,000 tons daily) after 18 months' trial, and their installation at the Alaska Gastineau (crushing 6000 tons daily) would indicate that the ball mill is the best machine available. Whether the ball mill will eventually replace the stamp is something worth watching in the future.

Under the caption[1] "Fine Grinding: Stamps and Ball Mills," Henry Hanson covers somewhat the same ground as Mr. Cutler, and says that more recently the use of the stamp as a primary crusher has become questionable, now that the ball mill, rolls, and disc-crusher vie with one another for economic supremacy in reducing a crusher-product to a suitable tube-mill feed. It is conceded that the stamp, if employed at all, should be used only as a primary or intermediate crusher in producing a suitable tube-mill feed. It might pay to scrap stamps for other machines, such as one-stage crushers. The reason, apparently, why single-stage stamp reduction is continued at the Homestake, Treadwell, and Mother Lode mines is that a good recovery is made when crushing to 20- or 35-mesh, amalgamating, and concentrating, when cyaniding the tailing as a whole is economically unprofitable. Stamps on the Rand are used largely as primary crushers, and Rand practice has, no doubt, influenced other millmen. Mr. Hanson does not consider the stamp so flexible, nor foolproof, and it is doubtful if the alleged advantage of being a good amalgamator holds. Stamps cost more, require more space, and power, and water than other machines, and make much noise. California millmen were loath to use any other machine, but at the Plymouth and Original Amador, Hardinge mills are a part of the flow sheets, the stamps being pushed

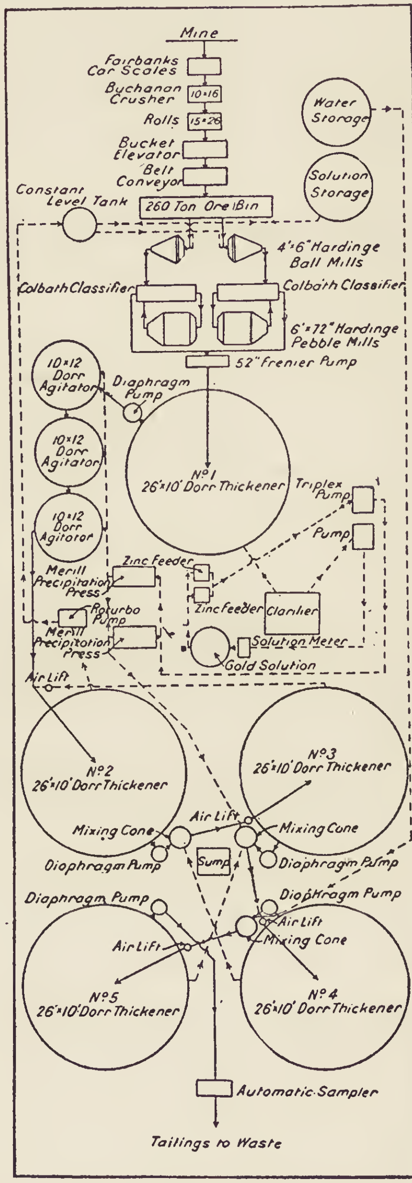


FIG. 6.—Flow sheet of Vipond mill.

[1] *Min. Sci. Press*, **112**, 701 (1916).

back to the position of primary crushers. Whether single-stage grinding in tube mills will prove most economical when an all-slime product is desired, or even whether the single-stage reduction is economically applicable to any kind of ore will bear further investigation, and no rule can be laid down at present. The length and diameter of tube mills is also discussed by Mr. Hanson, the use of steel balls instead of pebbles, liners, and the economical point of fine-grinding, all subjects not yet definitely settled.

In the use of worn-out stamp shoes by H. P. Orr, at a mine in Mexico, according to Grothe and Carter,[1] necks were cleaned on the face, put in sand, the surface liberally sprinkled with borax, and hard iron poured centrally into the mould formed by the pattern of the shoe, the result being a complete fusion of the iron to the steel neck. These improved shoes worked well in the battery.

An editorial by T. A. Rickard and discussion[2] on same by Courtenay De Kalb covered the stamp *vs.* ball-mill subject in good style, reviewing past practice and the present tendencies. Both writers, while trying to appear unbiased, lean toward the ball mill as a primary crusher.

Development of a modern ball mill will be found an interesting topic[3] at this time, especially as outlined in the descriptions of the Krupp, Hardinge, Ferraris, and Marcy machines.

As showing the tendency toward crushing in rotary mills and recovering the frequent gold solutions from pulp, the accompanying flow sheet of the Porcupine Vipond mill will give a good idea. No further explanation is necessary.

W. E. Cahill of Treadwell, Alaska, where there are 960 stamps crushing, and nearby the Alaska Gastineau mill using rolls, and the Alaska Juneau where Marcy mills are being installed, considers[4] that the stamp is worthy of further consideration. Stamps give a finished product in one operation, whereas with rolls, tubes, etc., there are a lot of other machines helping to complete the reduction of the ore, so that in terms of finished product the cost per ton is somewhat different. At the Alaska Treadwell mills the cost of crushing, tramming, stamping, and concentrating is from 27 to 32 cts. per ton; at the Alaska-Gastineau, crushing, rolls, tube mills, and concentrating, 33 cts. This does not show much advantage of the newer machines over stamps.

Chilean mills are used as both primary and secondary crushers, and in the past have been the subject of much discussion. Alexander McClaren compares[5] them with stamps. He considers that mechanical appliances

[1] *Min. Sci. Press*, **112**, 467 (1916).
[2] *Min. Sci. Press*, **113**, 260 and 339 (1916).
[3] Anon., *Met. Chem. Eng.*, **14**, 285 (1916).
[4] *Min. Sci. Press*, **113**, 79 (1916).
[5] *Eng. Min. Jour.*, **101**, 15 (1916).

intended to reduce ores from primary crusher down to finer than 200-mesh or so in one machine and at one operation have not yet been eminently successful, and then discusses results from the work of slow-speed Chilean mills used in various parts of reduction plants. The stamp frequently does work for which it is unfitted. As an ultimate fine grinder the cylindrical type of mill will probably always be used, yet it can be preceded with some machine that will do the duty of the stamp at far less cost, making a fine product and thereby lessening the duty of the tube mill. The work of three Lane mills (Chilean type) in Montana proved this. Another comparison was made with a Western mill in which stamps, high-speed Chilean mills, and tube mills were operated in series. A 10-ft. Lane mill gave results that compared favorably. Mr. McClaren's deductions were corroborative of some notable discussions on the Chilean mill in 1908, 1910, and 1912.

The mechanical efficiency of crushing was discussed[1] by A. O. Gates and H. Stadler, following some notes published in 1915. The former thinks that by forgetting Kick's and Rittinger's laws and studying his crushing operations by means of the crushing-surface diagram, they would do better. He also concludes that neither his or Stadler's work has resulted in any marked improvement in mill efficiency. Mr. Stadler's remarks were a personal reply to A. Del Mar, who wrote[2] in November, 1915. He then discussed stamp and tube-mill efficiency; and the "new metallurgy" on the Rand, based on Rittinger's law.

The installation of tube mills involved a good knowledge of mechanical engineering, owing to the great weight of material revolving on two bearings and the power consumed. Charles Labbe discusses[3] the erection of these machines. Short mills are easily supported on two bearings, but the 20- to 24-ft. mills require tires and rollers for support. The foundation should form a solid block of concrete the length of the mill. Rules are given for lining up the drive shaft. The setting of rollers is an important adjustment, as upon them depends the smooth running of the mill. Very little side-play should be allowed when the mill has herring-bone gears. Some practical hints are given on starting a new mill, stopping leaks, and shutting down.

The Mining and Metallurgical Society of America committee on standardization suggested a scale for measuring screen openings. The designation of screen sizes was thereupon discussed[4] by E. A. Hersam of the University of California. He considers that it will be wise to go slow in this matter. While common sense and personal preference will hold in the selection of screens, advantages may be gained by an understanding

[1] *Min. Sci. Press*, **112**, 366 and 399 (1916).
[2] *Min. Sci. Press*, **111**, 808 (1915).
[3] *Eng. Min. Jour.*, **101**, 777 (1916).
[4] *Min. Sci. Press*, **112**, 262 (1916).

of terms and the general use of such designations as can be understood. It is not the number of openings per linear inch, but the size of wire that becomes a factor in designating the coarseness of a sized product or crushed ore. One size of wire could not be adopted for all screens. It is the opening, and not the wire, that is the real and important feature of the screen. When the sizes of the openings of the screens are known, designating the coarseness of sized products by these sizes, is without question, the most exact, adaptable, and direct means of expressing sizes. The universal expression of the coarseness of material will come to be in terms of the coarseness of the screens that were used in sizing it. The expression of screen sizes by the dimensions of the aperture is simple and sufficient, and can easily be given in decimals of an inch. A screen having openings 0.050 in. in dimension could be designated by the number 50, and so on. It is desirable to discontinue allusion to the number of openings to the inch as an expression of the coarseness of the screen.

Amalgamation

Amalgamation of gold by copper plates may be spoiled by the addition of too much cyanide for dressing them, according to W. H. Washburn.[1] Fine gold was dissolved in one instance where a millman was adding several ounces every ½ hr. to the mortar boxes. Cyanide also hardens plates so that they will not absorb and hold mercury properly. The oxide also forms on the copper, preventing amalgamation.

Dredging

Gold dredging in the United States has yielded a total of approximately $120,000,000 to the end of 1916, of which California has contributed $87,000,000. In an advance chapter of "*Mineral Resources of the United States*, 1914," published by the U. S. Geological Survey in January, 1916, H. D. McCaskey gives interesting statistics on the industry. The annual output is now at the rate of $13,000,000, Alaska yielding $2,400,000; California, $7,800,000; Colorado, $700,000; Idaho, $600,000; Montana, $850,000, and other States the balance.

Gold saving on dredges was described[2] by Howard D. Smith, who said that little change has been made, until recently, in this important field. Tests and subsequent installations of gold-saving apparatus by the Natomas company have been highly beneficial. The accompanying drawing shows the equipment and its position on a dredge, consisting of Neill jigs taking the flow of sand and gravel from the tail-sluices, a Hardinge mill

[1] *Min. Sci. Press*, **112**, 297 (1916).
[2] *Min. Sci. Press*, **113**, 202 (1916).

(using pebbles from the tailing) to brighten the rusty gold, a shaking amalgamator, and copper plates. On No. 7 dredge the amalgamator recovery was from 11.4 to 19.8 per cent. of the total recovery; on No. 10, where there is less rusty gold, from 6.1 to 7.3 per cent. Pebble mills are not required on all the boats. These figures show what used to be lost in rushing the pulp over riffles, and what may be recovered by re-dredging the tailing.

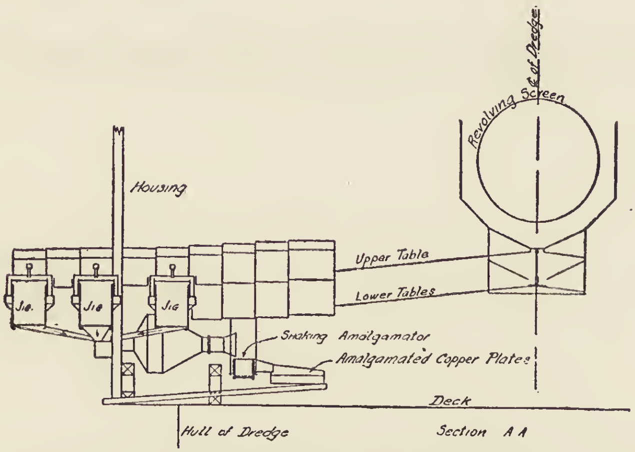


Fig. 7.—Gold-saving apparatus on a Natomas dredge.

Concentration

Although made in connection with the concentration of tin ore in Cornwall, England, the tests[1] with tables having glass surfaces should be of interest to gold and silver metallurgists. Table tops are most important in the concentration of any ore. In a comparison between glass and wood tops the former gave good results, but a complete scientific study of their value is desirable.

Although the question of freight, high treatment charges, and losses has been considered by companies producing concentrate from gold and silver mills, the general custom is to send this product to smelters. Even the simplest concentrate—gold-bearing iron pyrite—is smelted in many cases, local treatment at the mine not being a part of the operations. In his "Why ship concentrate?" discussion,[2] W. MacDonald states that there are instances where concentrate is shipped at heavy expense, although it could be locally treated to greater advantage. Practice on the Mother Lode of California is briefly touched upon. The Waihi mine in New Zealand was a pioneer in this branch of cyanidation, recover-

[1] *Min. Mag.*, Jan., 1916.
[2] *Min. Sci. Press*, **113**, 41 (1916).

ing from a gold-silver concentrate 95 per cent. of the metals for over 12 years. Fine-grinding and long contact with cyanide solution is the secret of this treatment. At Atlanta, Idaho, an out-of-the-way center, the concentrate contains 4 per cent. arsenic, also lead, zinc, and antimony in small quantities. This refractory product is now being cyanided successfully. At the Waihi Grand Junction mine, New Zealand, the concentrating tables are placed in circuit with the tube mill, and the concentrate together with coarse sand, is ground very fine, finally mixing with the other pulp for further treatment. Treatment is simplified by this method, and there is no concentrate to ship or bother about treating. Each concentrate presents its own particular problem, which may not be altogether a metallurgical one; local conditions may be a deciding factor.

Classification

Under the caption of "The Grading Industry" *Metallurgical and Chemical Engineering* published a series of articles by E. S. Wiard. The term "grading" is used in the sense of preparing material according to size or sizes, and in the majority of the grading industries the sizing is the finishing operation, following which the products are ready for the market. Mechanical problems arise in operations when grading is one of the necessary steps. Through the articles are discussed vacuum separators, Akins, Dorr, and Federal-Esperanza classifiers, examples of grading incorrectly termed "classifying," true classification in rising currents of water, screens, trommels, products of coarse and fine crushing, blinding of screens, factors in screening, etc. Regarding the term classifying, J. V. N. Dorr replied,[1] discussing the use of the word "classifier," and gave some details of work done by his own well-known machine. Nathaniel Herz discussed the probability and chance in screening in the same issue, correcting an error in calculating.

Thickening and Agitating

"Clay: Its Effect in Ore-Dressing and Cyanidation," was the title of a paper published in the *Mining and Scientific Press*, but originally read before the Institution of Mining and Metallurgy, in London, by A. W. Allen. The author considered colloids, absorption and adsorption of gold, and filtration of cyanide solutions. Mr . Allen compiled the paper to explain several points that have obtruded themselves in practical work, including the fact that a complete extraction of gold from even the finest slime is impracticable, and the facts adduced indicate that colloidal clay

[1] *Loc. cit.*, 295.

has more absorptive properties than has non-colloidal clay, and shows the powers which clays possess of retaining liquids and dissolved salts.

Although primarily written for flotation metallurgists, the series of papers[1] by E. E. Free and those[2] of Oliver C. Ralston, entitled "Colloids and Colloidal Slime," "Sedimentation and Flocculation," "Rate of Slime-Settling," "Properties of Slime Cakes," and "The Control of Ore Slime," respectively, should be of value to cyanide men, as in certain departments of cyanide and flotation mills the pulp problems are similar. All ore dressing requires the handling of colloids. Mr. Free starts with definitions of colloids, following with the properties of suspension, relation of suspensions and colloids, anomalies of colloidal slime, a conception of colloids, classification of colloids, colloid terminology, formulas for slime settling, causes of permanent suspension, flocculation and deflocculation, and agents for same, temperature and slime settling, the settling of thick suspension, possibility of selective settling, type of settling depending on concentration, size and shape of settling tanks, estimating slime-plant capacity, classification of theories of plasticity, classification of gelatinous colloids, application of principles to slime particles, control of the colloid condition, the function of sand in slime filtering, and a summary of data on permeability of slime cakes. Mr. Free's articles were carefully prepared and are important as providing a basis for intelligent theorizing on a highly technical subject. Concerning Mr. Ralston's papers it may be said that only a thorough knowledge of slime is required to enable the millmen to turn their qualities into advantageous ones, instead of the intractable material they have been usually considered. The principles of colloid chemistry are shown to apply to slime, and in the light of this information their behavior when handled by known processes is discussed.

The importance of efficient settling of slime was discussed by Paul W. Avery,[3] who says that the thickening of slime to a 1:1 or 1:1½ ratio (solid : liquid) is often a serious problem. He proceeded to explain how the economic limit of settling slime at a mine in Mexico was accomplished, and what were the improved results.

Clayey ore is a bother to mine, crush, and treat, and that from the Buckhorn mine in Nevada was no exception. According to Paul R. Cook[4] the ore deposit occurs as a shallow kaolinized mass of material with basalt rocks. Its specific gravity was 1.9. The ore contains 16 per cent. water of hydration, and the cyanidation of the ore offered unusual difficulties. The ore stuck in the bins. High-speed toothed rolls proved

[1] *Eng. Min. Jour.*, **101**, 249, 429, 509, 681, 1068, 1105 (1916).
[2] *Loc. cit.*, 763, 890, 990.
[3] *Min. Sci. Press*, **113**, 738 (1916).
[4] *Bull. Amer. Inst. Min. Eng.*, Sept., 1916.

satisfactory for crushing. In the Hardinge mill the clay plastered the balls to the side of the machine. Tube mills gave 80 per cent. passing 150-mesh. Of the mill-head value, 80 per cent. was dissolved in the crushing plant; only a little additional recovery was obtained in the rest of the plant. The real trouble was in settling the pulp and removing the dissolved value from the clayey pulp. Oliver filters could only work at 50 per cent. capacity on this pulp. The cost of treatment was $1.59 per ton. If fuel were cheap enough the ore could be dehydrated, after which treatment would be made much easier.

Slime settling, always of interest to the millman, was investigated[1] by H. S. Coe and G. H. Clevenger, who summarize as follows:

(1) In thickening pulps which are to be discharged at a consistence such that the discharge is still in the form of free-settling pulp, the depth of the tank is of little consequence. (2) When thickening pulps to a consistence where it is necessary to expel fluid by compression, sufficient capacity must be given the tank so that the pulp will be retained the necessary time to thicken it to the required density, and also to allow sufficient storage to compensate for fluctuations in the feed and discharge. (3) The consistence of discharge possible may be closely determined by allowing a cylinder of thick but free-settling pulp to settle, taking readings at intervals of a few hours up to the point where settling practically ceases. (4) The required area may be computed by applying the formula $A = \frac{2000}{\frac{24\,(62.35R)}{F-D}}$, where A is the area in square feet required to thicken 1 ton of 2000 lb. of solids to a consistence in the discharge of D (parts fluid to 1 part solid by weight) in 24 hr. (5) The required depth of the thickener may be ascertained by computing the capacity of the thickening zone to contain a supply of solids equal to the total capacity of the tank for the number of hours required to thicken the pulp to the density required in the discharge, to this depth adding an allowance for lost space due to the pitch of the drag in the thickener; also 18 to 30 in. for depth of feed, and a further allowance for storage capacity when the discharge may be closed. The authors gave a table of actual capacities and computed capacities of thickeners working at the Golden Cycle, Hollinger, Homestake, Liberty Bell, Nipissing, Portland, Presidio, Tonopah Belmont, and West End mills.

Cyaniding by continuous decantation at the Pittsburgh-Dolores and Rochester Mines plants is another article[2] that shows the steady spread of this system. Both mills are in Nevada. The first treats ore assaying 0.44 oz. gold and 3.4 oz. silver per ton. Reduction is by jaw-crusher,

[1] *Bull. Amer. Inst. Min. Eng.*, Mar., 1916.
[2] Anon., *Met. Chem. Eng.*, **14**, 435 (1916).

rolls, and tube mill, 75 per cent. passing through 200-mesh. The extraction is 92 per cent., at a cost of $2.69 per ton. The Rochester ore is mostly silver-bearing. Stamps and tube mills crush the ore, during which time 35 per cent. of the total silver dissolved goes into solution. Nos. 1 and 2 agitators dissolve 55 per cent. more, and No. 3 the remainder, 10 per cent. The loss of dissolved metal is only 2 to 3 cts. per ton.

C. F. Spaulding gives[1] his experience with the C. C. D. process, also discussing settling area for slime, thickeners, and transfer pipes.

Counter-migration of pulp and solution in cyanidation and acid leaching was analyzed[2] by Bernard MacDonald, who argues that since all-sliming has been generally adopted for cyanidation, metallurgists are directing their efforts to improving the apparatus. He then described the operation of his own tank—the Parral—showing advantages from its use.

Counter-current decantation, now known as the C. C. D. process, is increasing in use, and a good summary of the process is given by L. B.

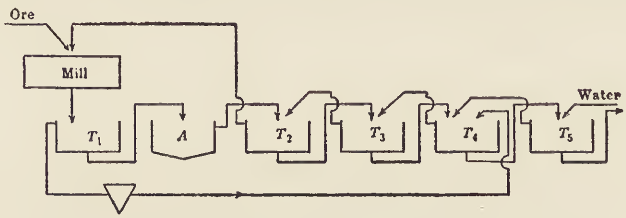


Fig. 8.—Typical flow sheet of counter-current decantation system.

Eames,[3] who traces its history from 1901, when the principle was first employed.

The accompanying sketch is a simple yet typical flow sheet of the C. C. D. system. It is assumed that crushing is done in cyanide solution, the overflow from the tank T_2 being used for the crushing solution. This solution leaves the grinding circuit with the ground pulp and enters T_1, and that part which does not pass to the agitators with the pulp overflows T_1, and goes to precipitation. After depositing its gold-content, it is used to dilute the underflow of T_3 as it enters T_4. The overflow of T_5 is also mixed into the feed to T_4. The overflow of T_4 mixes with the underflow of T_2 to form the feed to T_3, etc., as indicated in the flow sheet. At each succeeding mixture the solution meets a pulp of higher dissolved metal-content than itself, and is enriched while the pulp is correspondingly impoverished. The pulp at each step approaches the discharge end of the mill while the solution goes to the feed end—hence counter-current decantation.

[1] *Min. Eng. World*, **45**, 747 (1916).
[2] *Met. Chem. Eng.*, **14**, 283 (1916).
[3] *Bull. Amer. Inst. Min. Eng.*, Dec., 1916.

The principal factors that may affect the efficiency of the process are: (1) grade of ore; (2) ratio of solution precipitated to ore treated; (3) thickness at which pulp can be discharged; (4) cost of chemicals; (5) rapidity of dissolving, and the place in the circuit where it takes place; and (6) efficiency of precipitation.

At the Hollinger mill at Porcupine, treating 50,000 tons of ore monthly, the decantation plant at present consists of five rows of 40-ft. tanks, four tanks to a row, forming a plant of five units. The tanks are arranged with a difference in elevation of 2 ft. 6 in. between steps, with the final tanks of the series the highest, so that all solutions pass through and out of the plant to precipitation. The diaphragm-pumps used were designed by the company's staff and have been reliable and economical. Only one man is necessary for each shift. Power consumed by each tank is less than 1 hp., while each pump uses about the same. The cost of decanting is 2.09 cts. per ton. The recovery is almost the theoretical maximum. The moisture in tailing is 45 per cent., and the dissolved gold per ton of ore discharged is 9.75 cts.

Principles of filtration were analyzed[1] by D. R. Sperry in an informing manner. There are two distinct and constantly changing processes going on during filtration: (1) flow of liquid through porous mass; and (2) building up of the porous mass or cake. Mr. Sperry proceeds to discuss the rate of flow through the porous mass. The flow through a filter cake is a capillary phenomenon. Formulæ are given for flows. Other factors are permeability, and resistance to flow. Temperature affects a liquid's viscosity, thus influencing its capillary flow.

Clean-up and Melting

Precipitate from cyanide plants generally contains more or less base metals, which lower the fineness of the gold and silver bullion, resulting in higher Mint charges. It is certain that no two cyanide plants produce similar precipitates, and no two clean-ups and melts are performed alike. In Colorado, the Argo mill at Idaho Springs, treats custom ores that contain from a trace to 3 or 4 per cent. copper. Cyanide solution dissolves a good deal of this, which is precipitated on zinc thread along with the gold and silver. Jackson A. Pearce describes[2] the refining of this cupriferous precipitate, which contains 21.6 per cent. copper, 4.3 per cent. gold, and 13.8 per cent. silver. Ordinary methods of treatment are not applicable, on account of the high silver- and copper-content, and a wet method was therefore evolved for elimination of the copper. The copper is oxidized by treating the precipitate with sulphuric acid, then

[1] *Met. Chem. Eng.*, **14**, 198 (1916).
[2] *Min. Sci. Press*, **112**, 270 (1916).

adding manganese dioxide. Owing to the presence of finely divided electro-positive copper, the silver is re-precipitated as metallic silver. The silver eventually comes into solution, and is precipitated by a small quantity of the original zinc-box sludge. This silver precipitate, and the gold in the first treated precipitate, is filtered, washed, dried, and melted. A 20 to 30 per cent. copper sludge is reduced to 2 to 4 per cent. copper in 2 hours. Bullion formerly 550 to 750 fine is now produced 900 fine. There is a saving in fluxes, crucible, time of melting, transport, and Mint charges. The filtrate assaying 0.005 oz. gold and 0.03 oz. silver per ton, and 3 to 4 per cent. copper is run over scrap iron to recover the copper.

Raw gold precipitate at the Liberty Bell cyanide plant, Telluride, Colo., contains from 25 to 75 per cent. gold and silver, 18 to 30 per cent. zinc, 0.5 to 52 per cent. lead, 0.5 to 20 per cent. copper, 1 to 5 per cent. silica, 4 to 8 per cent. calcium oxide, and 0.5 to 8 per cent. sulphur, according[1] to A. J. Weinig. All methods of wet refining, that is, with acid, were unsatisfactory. The process is to mix the wet precipitate with a computed flux of manganese dioxide, potassium or sodium nitrate, sodium carbonate or soda-ash, silica, and borax. This is agglomerated in a muffle and melted. By this means the various impurities are oxidized and driven into the slag in a definite order, namely, zinc, sulphur, lead, and copper.

From precipitate to bullion is the subject discussed[2] by R. R. Bryan, who, like all cyanide men, dislikes the clean-up. At this stage of milling, precious metal can easily be lost and the bullion debased. Details are given of acid treatment, fluxing, slag, and discussion as to what point it is profitable to refine.

For the melting of cyanide precipitate there are three practical furnace methods, namely: (1) direct cupellation; (2) reverberatory hearth; and (3) blast-furnace, according to Regis Chauvenet.[3] He discusses the last-mentioned system, quoting largely from J. W. Hutchinson of Goldfield, Nevada, who wrote a series of articles[4] in 1911, in which this was included. Mr. Chauvenet then gives examples of calculation of furnace charges and the behavior of slags.

Extraction and Cost

Discrepancies in cyanidation are analyzed[5] by Edmund Shaw. Checking the theoretical extraction (by assay) of the mill with the bullion actually recovered is often found difficult. The bullion plus tailing method of arriving at extractions is no check on treatment results. The

[1] *Bull. Amer. Inst. Min. Eng.*, Mar., 1916.
[2] *Min. Sci. Press*, **113**, 834 (1916).
[3] *Met. Chem. Eng.*, **14**, 96 (1916).
[4] *Min. Sci. Press*, **104**, May-June.
[5] *Min. Sci. Press*, **113**, 92 (1916).

causes of any difference between theoretical and actual extraction are theft, leakage, and waste, errors in estimation of tonnage, errors in sampling, and errors in assaying. Each of these is discussed by Mr. Shaw and remedies are suggested for this important subject.

For the Second Pan-American Congress, held at Washington, D. C., in December and January, 1915–16, G. H. Clevenger presented a paper, entitled the "Hydro-metallurgical Treatment of Complex Gold and Silver Ores." The term "complex ore" has never been clearly defined, but metallurgists understand its significance. A history of wet methods of ore treatment was given, starting at the year 1540, and bringing them down to the present time, discussing certain features of each process, especially cyanidation. Examples given showed the gold recovery at the Homestake (94.6 per cent.), Alaska Treadwell (91 per cent.), Cripple Creek (95 to 98 per cent.), Goldfield Consolidated (89.36 per cent.), Tonopah Belmont (93 per cent. silver, 96.2 per cent. gold), San Rafael, Mexico (91.43 per cent. silver, 97.08 per cent. gold), and Nipissing (99 per cent. silver), and Alaska Gastineau (84 per cent.). Five proposals suggested methods suitable for as many classes of gold and silver ores.

Milling and cyaniding costs at Grass Valley and Nevada City, Cal., were tabulated[1] by R. E. Tremoureux and F. A. Vestal. The plants of the North Star and Empire companies were considered. On 263,060 tons of ore treated by all, the cost of milling was 29.6 cts. per ton, and of cyaniding 49.1 cts.

Treatment of Silver Ore

Silver-ore treatment at Tonopah is a fairly settled routine, and little new is written on the district. In the annual report of the West End Consolidated, Jay A. Carpenter gave interesting remarks on mill practice. This stamp-mill and cyanide plant treated 156 tons daily, of which 39 tons was mixed custom ore. The ore assayed 0.245 oz. gold and 23.42 oz. silver, the custom ore varying from $6 to $96 per ton. Such variations in value made it impossible to regulate the chemical consumption. The recovery was 94.8 per cent. of the gold and 90.88 per cent. of the silver. Cyanide consumption was 2.9 lb., and zinc thread 1.16 lb. per ton of ore. In spite of higher prices for supplies the cost was 3 cts. lower per ton, the total being $2.97 per ton. Useful trials were made in the use of manganoid steel balls against Danish and Nevada pebbles, also with Komata steel tube-mill liners. A large saving was made by studying mill solutions, decreasing the amount of cyanide and zinc used. Flotation was tried, but at present there is no field for the process.

Silver ore assaying between $15 and $25 per ton is treated at the

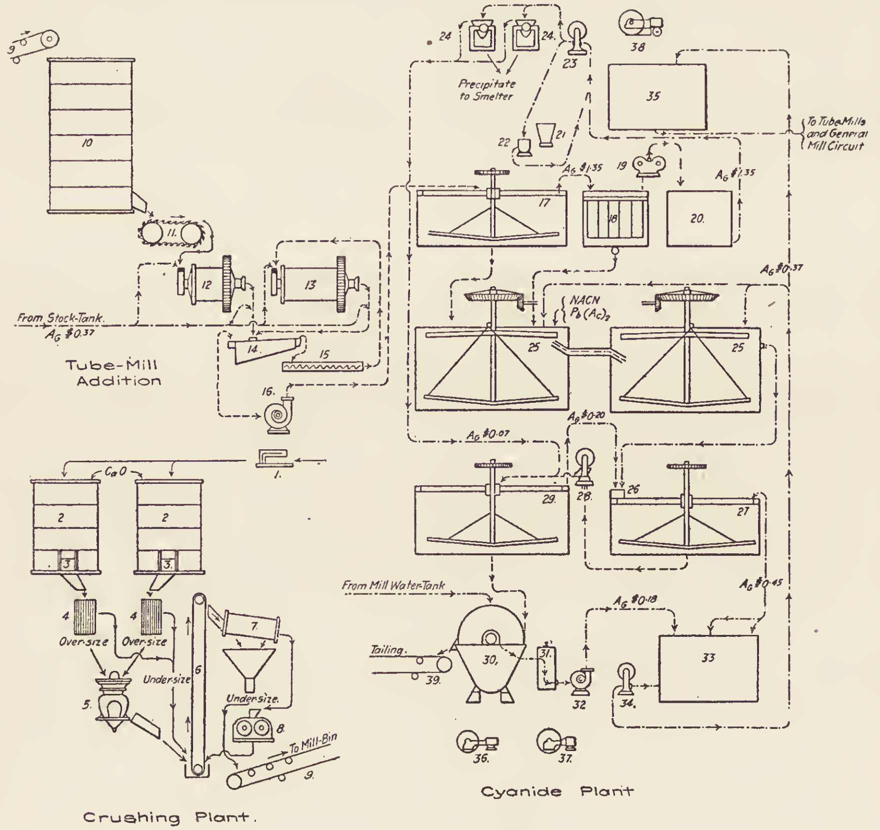
[1] *Min. Sci. Press*, **113**, 706 (1916).

Nevada Wonder mill, at Wonder, Nev., according to A. C. Damin.[1] The jaw-crusher, ten 1400-lb. stamps, screens with ½ by 1-in. openings, Trent Chilean mill, and 5 by 22-ft. tube mill, with cyanide plant, was designed to treat 75 tons daily; but by making a few changes in tank arrangement, the capacity is now 157 tons. Dorr thickeners, Pachuca agitators, and Oliver filters are used, precipitation being on zinc thread. The recovery of silver is above 90 per cent.

An argentiferous sulphide containing 4 oz. silver and 0.35 oz. gold is cyanided at the Comacaran mine in Salvador, according to A. B. Peckham.[2] The gangue is quartz and limestone, and is hard. Stamps crush 7 tons each daily in cyanide solution through 3-mesh. Tube mills grind the pulp to slime, which is thickened and agitated in apparatus that is a combination of mechanical agitator and Parral tank; later on it is treated in Pachuca tanks. The final treatment is by continuous decantation (C. C. D. system), for which there are advantages and disadvantages. Zinc thread is used for precipitation.

At Rochester, Nev., a silver-gold district, there are two mills, the Rochester Mines and Nevada Packard. The former is a typical equipment of the continuous counter-current decantation system. Thickeners are used exclusively without a filter. The ore is crushed by stamps and tube mills so that 94 per cent. passes 200-mesh. R. B. Todd described[3] the Nevada Packard soon after it was started in 1916. The ore treated is a silicified schist interspersed with quartz stringers; it is easily crushed. Treatment consists of a McCully crusher, screen, Garfield rolls, grinding in tube mill with cyanide solution to 200-mesh, thickening agitation, and final treatment of the pulp by counter-current decantation, an Oliver filter doing the final dewatering. In September, after the mill had been running for 8 months, H. G. Thompson gave[4] further details. He described the ore as a highly altered seriticized rhyolite, of varying hardness, traversed by quartz veinlets. Cerargyrite, the chloride of silver, is the valuable constituent. The content ratio of gold to silver is 1 to 300. Two short tube mills—6 by 5 ft. and 6 by 10 ft.—working in closed circuit with a Dorr classifier, grind a ⅜-in. roll product so that 83 per cent. goes through 200-mesh. At No. 1 tube-mill feed-box the ore receives first contact with cyanide solution. Selected lumps of rhyolite have largely replaced Danish pebbles, being efficient and economical. Frenier spiral pumps are found satisfactory. A combination of the C. C. D. system and revolving drum-type filter recovers the silver-bearing solution. Silver is precipitated by the Merrill zinc-dust system. With a recovery

[1] *Eng. Min. Jour.*, **102**, 927 (1916).
[2] *Min. Sci. Press*, **112**, 639 (1916).
[3] *Eng. Min. Jour.*, **101**, 245 (1916).
[4] *Min. Sci. Press*, **112**, 377 (1916).



- 1 Fairbanks Recording Beam-Scale.
- 2. 12'x 16' Steel Ore-Bins.
- 3. 18"x 24" Steel Ore-Bin Gates.
- 4. 20"x 45" Grizzlies, 1½" spaces.
- 5. Nº 5 McCully Gyratory Crusher, Superior Type
- 6. 14" Belt and Bucket-Elevator, 12"x 6" Mall Buckets
- 7. 30"x 9'3" Trommel, 2-mesh, Nº 10 Wire Screen.
- 8. 15½"x 37" Garfield Rolls.
- 9. 14" Conveyor-Belt.
- 10. 15'x 28' Steel Ore-Bin.
- 11. 2'x 6' Steel Apron-Feeder.
- 12 5'x 6' Tube-Mill.
- 13 6'x 10' Tube-Mill
- 14. Dorr Duplex Classifier.
- 15 8"x 9' Screw-Conveyor.
- 16. Nº 1 Frenier Pump
- 17. 10'x 28' Dorr Thickener.
- 18. 10'x 12' Clarifying Tank - 16 - 5'x 8' Butters' Leaves.
- 19. 2" Rotary Force-Pump, "Gould."
- 20. 10'x 12' Pregnant Solution Tank.
- 21. Merrill Zinc-Dust Feeder
- 22. Zinc-Dust Emulsifier
- 23. 5½"x 6" Deane Triplex-Pump.
- 24. 36" Merrill Precipitating-Presses, 16 Frame.

Dry Ore ————
Pulp. – – – – –
Solution —·—·—·—
Water —··—··—··—

- 25. 16'x 28' Dorr Agitators.
- 26. Feed-Box.
- 27 10'x 28' Dorr Thickener.
- 28. Nº 4 Diaphragm Pump, Colorado Iron Works Type.
- 29. 12'x 28' Dorr Thickener.
- 30. 11'6"x 12' Oliver Filter.
- 31. Vacuum-Receiver
- 32 2" Krogh Centrifugal Pump.
- 33 12'x 20' Sump-Tank
- 34. 5½"x 6" Deane Triplex Pump.
- 35. 12'x 18' Stock-Tank
- 36 14"x 12" Dry Vacuum-Pump.
- 37. 12"x 8" Ingersoll-Rand Air-Compressor, Low Pressure.
- 38. 13" & 7½"x 12" Ingersoll-Rand Air-Compressor, for Mine
- 39. 12" Belt-Conveyor.

FIG. 9.—Flow sheet of Nevada Packard mill.

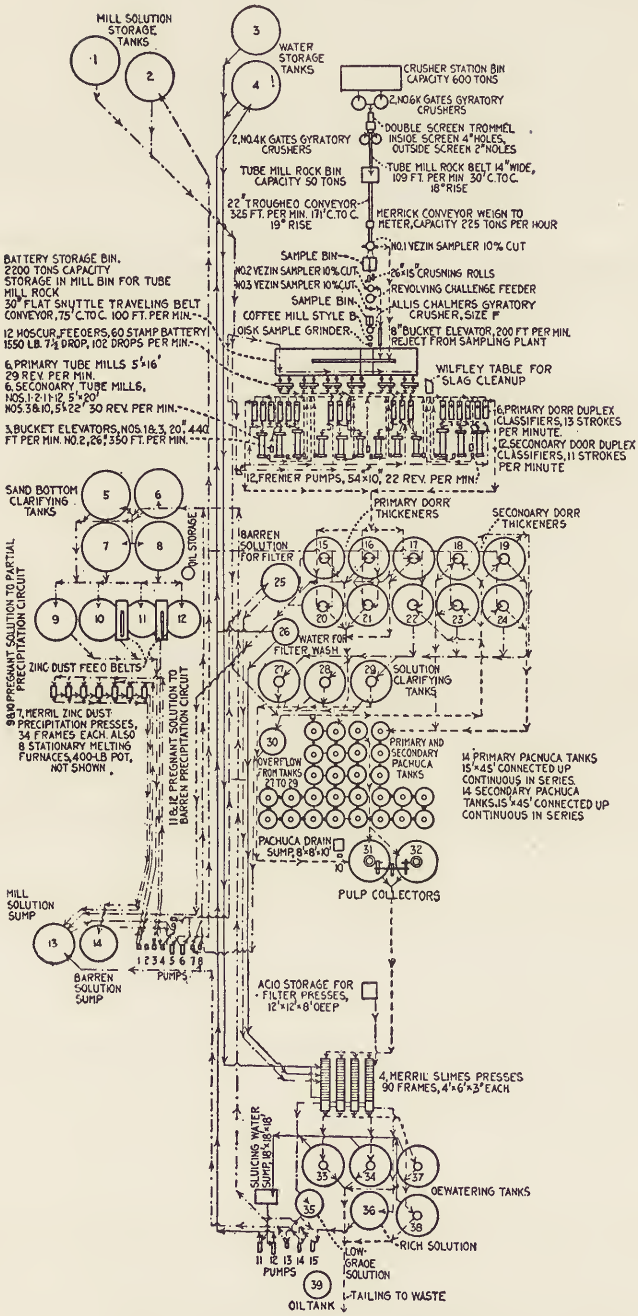


Fig. 10.—Flow sheet of Santa Gertrudis mill.

of 95 per cent. the cost is $1.23 per ton. The addition of lead acetate to the pulp is necessary, otherwise the extraction falls off. The mill cost $65,452, against an estimate of $65,740 by Knud Freitag.

It may be said that many metallurgists have wished to describe the Santa Gertrudis mill at Pachuca, Mexico, and several technical journals have tried to get a write-up of the practice, but it remained for the general manager, Hugh Rose, to do this for the American Institute of Mining Engineers.[1] The daily capacity is 1100 tons, but difficulty in getting supplies prevents more than 60 per cent. being operated. The accompanying drawing is almost self-explanatory. Mine rock is used in the tube mills. The economical grinding point is 75 per cent. through 20-mesh. Lime consumption is 20 lb. per ton. Crude litharge is used instead of lead acetate. The Merrill zinc-dust process of precipitation has justified its adoption. The bullion assays 940 silver and 5 gold, per 1000.

Native silver has been mined in Chihuahua, Mexico, since the 17th century, according to W. M. Brodie.[2] The low-grade ores were discarded until 1880, when they were developed on a large scale. The rich ore is now separated, and crushed in a special stamp-mill. The coarse metal is taken out of the mortar and melted. The pulp from the screens is treated in pans with quicksilver, and the tailing leached with cyanide solution by agitation. The poorer ores are crushed in larger plants, concentrated, the richer part of the concentrate is amalgamated, and the poorer part leached by percolation. Native silver and argentite concentrate well.

Kalgoorlie, Western Australia, produces a sulpho-telluride ore, the gold predominating. Any increase in silver-content upsets the regular treatment by lowering the gold recovery. The staff of the Great Boulder Perseverance company recently investigated[3] the cause of its residue rising to 74.2 cts. per ton from 54 cts. Treatment conditions were good during the period, roasting being better than normal. The feed was reduced, stronger cyanide was used with more alkali, and larger agitation, without avail. It was ascertained that the higher residue was due to the unusually high silver-content of the ore; and it is easier to dissolve gold *per se* than when combined with silver, and as the latter increases so does the rate of solution of the gold decrease. The increased silver probably came from one of the silver tellurides.

Special Problems

Antimony-gold ore treatment has occupied the attention of metallurgists in Australia, Rhodesia, and Mexico, with indifferent results. W. S.

[1] *Bull. Amer. Inst. Min. Eng.*, Aug., 1916.
[2] Paper read before Pan American Congress at Washington, D. C.
[3] *Min. Jour.*, Chamber of Mines.

Mann gives[1] results of a mill test made in southern Mexico. The ore was crushed in a 5 per cent. solution of caustic soda, the gold amalgamated on plates, and the pulp then concentrated. Slime was dewatered and the water sent to a storage tank, where the antimony was precipitated. The soda solution was brought up to strength for re-use. The sand was cyanided by percolation and the slime agitated and decanted.

F. H. Mason stated[2] that the trouble with ore from the West Gore mine in Nova Scotia was not the removal of the caustic soda, prior to cyaniding, but that in parts of the mine the ore contained a good deal of metallic antimony, which is not soluble in caustic soda, and which, remaining in the pulp, formed a precipitant for any gold that the subsequent treatment with cyanide dissolved, and thus prevented its removal from the pulp. The MacArthur process, tried in New South Wales and Rhodesia, consists in leaching the pulverized ore with a 2 per cent. solution of caustic soda until the sulphide of antimony was used, thus:

$$Sb_2S_3 + 6NaOH = Na_3SbS_3 + Na_3SbO_3 + 3H_2O.$$

Carbon dioxide from burning of limestone passed through the antimonial solution, precipitating the metal as sulphide, thus:

$$Na_3SbS_3 + Na_3SbO_3 + 3CO_2 = Sb_2S_3 + 3Na_2CO_3.$$

The solution was removed from the antimony sulphide by decantation and filtration, and converted into sodium hydrate, ready for use again, by caustic lime:

$$Na_2CO_3 + CaO + H_2O = 2NaOH + CaCO_3.$$

Near Nome, Alaska, is the Sliscovich mine, which produces an ore assaying from 18 to 40 per cent. antimony and from 0.1 to 0.2 oz. gold per ton. The gold is not evenly distributed, occurring in bunches enclosed in the quartz. The stibnite and quartz are so finely intermixed that coarse-concentration methods are impossible, according to E. R. Pilgrim.[3] At the University of Washington School of Mines, flotation trials were made on this ore, showing that best results were obtained by grinding through 150-mesh, and using wood-creosote. Of the gold, nearly 100 per cent. was recovered; of the antimony, 92.4 per cent.

In the Province of Otago, New Zealand, in Korea, and in Idaho, the separation of gold from tungsten was one of the problems at several mines. According[4] to C. W. Gudgeon, the Golden Point mine in New Zealand yields 0.5 to 1 oz. gold ore from No. 2 vein, highly impregnated with scheelite. The best ore is hand-graded to 60 or 65 per cent. WO_3. The poorer

[1] *Min. Sci. Press*, **112**, 433 (1916).
[2] *Min. Sci. Press*, **112**, 542 (1916).
[3] *Eng. Min. Jour.*, **102**, 820 (1916).
[4] *Bull.* 21, Austral. Inst. Min. Eng.

ore is crushed by stamps, the coarse gold is amalgamated, Wilfley tables save the scheelite and pyrite, and the sand is cyanided. Concentrate is roasted to the magnetic sulphide stage, then separated electrically, making an iron-gold and a scheelite product. The iron product is roasted and treated again, giving an iron product containing 5 to 6 oz. gold per ton, and 61.2 per cent. WO_3. Treatment costs $1.38 per ton of ore. The Glenorchy mine produces a dense quartz, containing gold, scheelite, iron, and arsenical pyrite. The coarse scheelite was picked out by hand. Wilfley tables save the mineral. If pyritic, the concentrate is roasted and re-dressed to 70 per cent. WO_3. From 5400 tons of ore the recovery was 7.09 per cent. WO_3 and 45 cts. gold per ton.

In the Grass Valley district is the Union Hill gold mine, and according to P. B. McDonald,[1] where the quartz veins traverse a wide sedimentary series of black slate, quartzite, and intermediate phases, scheelite (tungsstate of lime) is found. The high-grade scheelite is picked out by hand and graded for shipment. The gold ore is crushed by stamps and the gold amalgamated.

Prior to the revolution in Mexico considerable interest was taken in the problem of treating the manganese-silver ore of the El Favor mine, Hostatipaquillo district, State of Jalisco. Since April, 1914, the mine has been idle, but experiments have been continued in the United States by Walter Neal, and others under his direction. While the work is not complete, progress was detailed[2] by Mr. Neal. The insolubility in cyanide of silver in certain ores where it is accompanied by manganese oxides is fairly well known, but the problem is complicated by the fact that the exact nature of the rebellious mineral is not known—whether there is a definite chemical combination of the manganese and the silver, or whether the manganese functions as an insoluble coating over the silver mineral is not yet known. Not all silver ores carrying manganese oxides are rebellious, and not all the silver in a given rebellious ore is insoluble. Only the manganese occurring as oxide interferes with the solubility of the silver in the ore. El Favor ore contains 20 oz. silver and 0.075 oz. gold per ton, also 3.49 per cent. manganese, 0.67 per cent. sulphur, 0.7 per cent. iron, and 0.42 per cent. calcium. The vein is quartz in andesite. In the higher-grade ore the silver is often observed as a chloride, but direct observation of its rebellious form in this ore is lacking. The gold yields 90 per cent. extraction by cyanide. The possibilities of hydraulic concentration were tried in all ways, but tests made at the mine by wet concentration offered no promise. The Huff Electrostatic process was tried. At the Massachusetts Institute of Technology, E. D. Bugbee recommended magnetic

[1] *Min. Sci. Press*, **112**, 40 (1916).
[2] *Jour. Chem. Met. Min. Soc. So. Afr.*, **17**, 9 (1916).

separation on Wetherill machines, followed by chloridizing roasting and cyaniding of the calcine, and direct cyanidation of the Wetherill tailing. This process offered improvements, but involved dry crushing at the mine. Henry E. Wood, of Denver, discouraged further work along concentration and cyanidation. Bromo-cyanide gave no benefit. This firm suggested chloridizing roasting, as giving 85 per cent. recovery. The tests of the Mechanical Wedge Furnace Co. corroborated those of Mr. Wood fairly well, but volatilization of silver is high—12½ per cent. Other processes were tried. All work done has indicated the necessity of completely decomposing the manganese in the ore before a satisfactory silver extraction can be obtained. Many tests involved the removal of the manganese with sulphur dioxide, salt solutions, salt with cyanide, salt and ferrous sulphate, and hyposulphite of soda. After complete dissolution of the manganese it was evident that the silver was all soluble in cyanide. Flotation experiments were made at Salt Lake City. On the raw ore results were unpromising. Flotation was tried in all kinds of solutions and with various oils. Flotation after sulphidization was next tried. It was learned early in these trials that silver rebellious to cyanide was equally rebellious to flotation. In summarizing results Mr. Neal says that he prefers a chloridizing or a reducing roast, followed by cyaniding, for El Favor ore. Flotation, although attractive, does not offer a solution of the problem.

In the subsequent discussion on this paper, H. A. White, basing his deductions on experiments, considered that it is obvious that some oxide of manganese is responsible, and then only when total silver is not in form of sulphide. Probably no method that does not involve the destruction of MnO_2 can yield a high extraction. He suggested that carbon monoxide, which has a powerful action on manganese dioxide, might be used.

Precipitation

Aluminium dust is used for precipitating silver from cyanide solutions, for making ammonal (an explosive), and in welding by the thermit process. Manufacture of the powder was described[1] by G. H. Clevenger, who stated that the granules formed by forcing gas or air into molten aluminium are powdered in ball mills. The dust is separated and polished. To prevent welding of fine particles during crushing, stearine or some wax is added. Frictional electricity is also produced during grinding, and is not readily conducted away on account of the insulating film of oxide. When this film does break, sparks occur, which ignite the gaseous mixture

[1] *Min. Sci. Press*, **112**.

formed by carbon in the aluminium, water vapor, and the wax, resulting in an explosion. Aluminium dust contains 91.2 per cent. Al, 5.8 per cent. Al_2O_3, 0.23 per cent. C, 1.07 per cent. H_2O, and 1.3 per cent. SiO_2.

As mentioned in another part of this review, the price of aluminium dust has risen so high (up to 90 cts. per lb.) that other precipitants for silver from cyanide solutions are being tried, more especially sodium sulphide. In the November *Bulletin* of the Canadian Mining Institute, R. B. Watson of the Nipissing mine gave results of its use at that property. The principle of the process is that the various sulphide combinations of silver are decomposed by contact with metallic aluminium in a caustic-soda solution, as follows:

(1) $2NaAgCN_2 + Na_2S = Ag_2S + 4NaCN.$

(2) $2Al + 5NaOH + 3Ag_2S = Na_2Al_2O_4 + 6Ag + 3NaHS + H_2O.$

(3) $2Al + 8NaOH + 3Ag_2S = Na_2Al_2O_4 + 3Na_2S + 6Ag + 4H_2O.$

The theoretical amount of aluminium needed to desulphurize 1 oz. of silver is 0.0057 lb.; in practice it is 0.006 lb. After the sodium sulphide is dissolved by barren solution it is mixed with the pregnant solution, and then pumped to a Merrill precipitating press. When full of silver sulphide precipitate a press contains 25,000 oz. of metal. This is mixed with caustic soda (0.03 lb. per oz. of silver) solution of 8 per cent. strength, and stirred. Above the vat in which this is done is a tube mill 15 in. in diam. and 72 in. long, containing 300 lb. of aluminium ingots. A centrifugal pump circulates the pulp from the tank through the tube mill for 10 or 12 hours. In another press the pulp is washed for 2 hrs., then mixed with borax, charged damp into a reverberatory furnace, and melted to metal 996 fine. There is a regeneration of cyanide in the process, as with aluminium-dust precipitation. Comparing pre-war prices for the reagents, the sodium sulphide method costs 0.4550 cts. per oz. of silver, against 1.1626 cts. by aluminium dust; or on 2,000,000 oz. per year a saving of \$14,150. The sodium-sulphide process is limited in application to silver ores, as gold sulphide does not precipitate in this way.

In his paper[1] "Electrolytic Precipitation from Cyanide Solutions," G. H. Clevenger discusses the possibilities of electrolysis as a precipitant in cyanidation. While previous attempts have been partly successful, the great area of cathode surface required and the difficulty of providing proper solution agitation have been serious obstacles. A table shows the results of several processes at mines in America, Africa, and Mexico. The following sentence is significant: "Much has been said regarding the regeneration of cyanide when electrolytic precipitation is used. My own experience is that with anything like complete precipitation little gain in cyanide strength can be hoped for."

[1] *Eng. Min. Jour.*, **102,** 579 (1916).

Electrolytic precipitation of precious metals from cyanide solutions still has its advocates, and P. H. Crawford gives[1] notes on later work at Minas Prietas in Mexico. These included assays of the solutions, anodes, cathodes, cells, alkalinity, current, and costs.

Descriptions of Certain Mills

Metallurgy of the Ashanti Goldfields Corporation ore was briefly discussed by W. R. Feldtmann[2] in dealing with the mines of the company. The ore deposits are lenses of quartz within a graphitic schist. Part of the gold is free, the remainder being in iron pyrite and other sulphides. Ordinary stamp-milling and amalgamation was applied to the outcrop ore, followed by cyanidation of the tailing. This system was unsuited for the deeper ore. The difficulty in cyanidation was probably due in part to the gold being held by arsenical minerals, and partly it was proved to be the result of action of the graphitic material in the ore, which causes premature precipitation of the gold from solutions. Instead of laboratory tests, experiments in bulk were carried out. The central treatment plant consists of two rotary driers, nine No. 5 Krupp ball mills, seven Edwards duplex roasting furnaces, conveyors, elevators, etc. The hot roasted ore is cooled by sprinkling on large floors, then transferred to 42 leaching vats of 140-ton capacity each. Treatment occupies from 10 to 20 days. The maximum capacity of this plant is 9500 tons per month, giving good results. Ore treatment costs $3.20 per ton.

A feature of the Babilonia Gold Mines plant in Nicaragua is the two Holman pneumatic stamps for crushing. S. M. Parker describes[3] this mill. The stamps, dropping 145 times per min., crush 28 tons each per 24 hr., through 6- to 9-mesh screens. Two pans grind the stamp pulp through 60-mesh. Filtration is by a vacuum machine. The recovery is 94.5 per cent., and cost $3.076 per ton.

Near Prescott, Ariz., the Big Pine Consolidated company has an interesting 80-ton plant at work, completed toward the end of 1916. C. H. Dunning states[4] that the ore consists of fragments of altered quartz-diorite of variable size cemented together by quartz carrying gold, silver, and iron. The ore is oxidized to a depth of 500 ft. and averages $9.50 per ton. Reduction is done by jaw-crusher, rolls (to be replaced by a ball mill), and tube mill, producing 100-mesh pulp. Mine ore and diorite pebbles from a creek are used in the tube mill. A true slime is not made, but rather a granular product that settles readily. Up to the No. 1

[1] *Min. Sci. Press*, **112**, 634 (1916).
[2] *Min. Mag.*, May, 1916.
[3] *Min. Sci. Press*, **113**, 911 (1916).
[4] *Eng. Min. Jour.*, **102**, 1043 (1916).

thickener the extraction is 75 per cent. Agitators are of a modified Parral type, consisting of an annular tank, 3 ft. wide, surrounding 24-ft. Dorr thickeners. Air lifts circulate the pulp, the agitator discharging continuously to the thickeners. A feature of one of these agitator-thickeners is the natural counter-current flow of pulp and solution theoretically possible. The Merrill system of precipitation is in use. Costs total $1.37 per ton.

All the ore of the Sons of Gwalia mine in Western Australia requires sliming, including the pyrite, according to T. B. Stevens.[1] To a depth of 3100 ft. the ore consists of 68.4 per cent. silica, 9.71 per cent. alumina, 1.85 per cent. ferric oxide, 3.61 per cent. calcium oxide, 11.04 per cent. calcium carbonate, 2.15 per cent. magnesium oxide, and 3.15 per cent. iron pyrite. The gold value is $7.20 per ton. Pyrite in schist is the richest part of the ore. The economical limit of grinding is 150 mesh. This is accomplished by a Gates crusher, 1150-lb. stamps (screens with an aperture of 0.07 in.), grinding pans, and tube mills. The pulp is porous and the vacuum-filter has a high duty. A 3-in. cake can be obtained in 20 min., using a 27-in. vacuum and 40 per cent. pulp. Washing occupies 60 min. Precipitation is on zinc thread. The bullion contains 799.3 parts gold, 81 silver, 32.5 lead, 9.3 iron, and 12.1 zinc. The cost of treatment on 13,534 tons monthly is $1.39 per ton.

Cripple Creek metallurgical progress, from 1894 on, was discussed by Philip Argall in an interview,[2] in which he gave interesting history of early cyanidation, roasting, chlorination, and treatment of the Independence $3 dump ore, at a cost of $1.51 per ton. In 1893 treatment costs at Cripple Creek were $15 per ton; in 1913, $1.38.

In its "Milling Number,"[3] the *Engineering and Mining Journal* published the following practical papers: "Choosing the Mill-site," by E. S. Wiard; "Operating Costs at the Liberty Bell" ($1.394 per ton); "Apparatus Used in Flotation," by Herbert A. Megraw; "Use of Belt-Conveyors," "Don Luis Charmes Fremain Steam Stamp," by M. R. Lamb; "Cyaniding Copper-Bearing Ores," by P. W. Gaebelein; "The Wrong Mill," by Charles Labbe; "Cyaniding Costs at Douglas Island, Alaska" ($3.254 per ton of concentrate); "Flotation of Flour Gold," by R. W. Smith; "Froths Formed by Flotation oils," by W. A. Mueller; "Belts and Bucket Elevators," by A. O Gates; "Air-Lifts at a Cyanide Plant," by P. W. Gaebelein; "Use of Oils in Flotation," by Herbert A. Megraw; and "Crushing and Grinding Machinery." While these are all important subjects, and are well-written articles, the matter is well known and requires no further abstracting.

[1] *Month. Jour.*, Chamber of Mines, Kalgoorlie.
[2] *Min. Sci. Press*, **112**, 119 (1916).
[3] July 1, 1916.

"Gold Milling in Amador, Cal.,"[1] by E. B. Durham, was supplementary to a review of metallurgy in that region[2] by M. W. von Bernewitz, published 2 years before, covering new plants and improvements in old ones. The Plymouth Consolidated was the first to use Hardinge mills on the Mother Lode, and was followed by the Original Amador company. The Plymouth also introduced belt conveyors to carry ore from the shaft to the mill, and the use of classifiers to deliver a uniform pulp to the vanners. Tailing from the Fremont mill is treated by lessees nearby. This product is tube-milled, concentrated on 10-tier rotary tables and the concentrate cyanided.

Flotation of Gold and Silver Ores

On Dec. 11 the U. S. Supreme Court handed down an important judgment on the flotation litigation between the Minerals Separation and J. M. Hyde (really the Butte & Superior Mining Co.) This decision is just as important for the gold and silver producers as to the base-metal companies. Generally speaking, the M. S. company was upheld. Minerals Separation says that there are 234 infringers of its patent in the United States—copper, gold, lead, silver, and zinc producers. The flotation company defines the claims held valid by the Court as those applying to the use of a fraction of less than 1 per cent. oil; those held invalid as covering the use of an unspecified quantity of oil; and those not considered as applying to the recovery of the oil coating from the mineral, the adding of soap to the process, and the removal of oleic acid from the mineral.

In its issue of May 15, *Metallurgical and Chemical Engineering* published a symposium on the cyanidation of flotation products, and the influence of flotation on the relative importance of cyanidation as a metallurgical process. The questions were as follows:

1. Are oil-flotation products—concentrates and tailings—as readily cyanided as similar products from ordinary wet concentration?

2. To what are the difficulties, if any, to be ascribed, and what are the remedies?

3. Are the difficulties likely to prove serious enough to react against cyanidation and restrict its use?

4. Is it possible that a combination of flotation plus smelting may in some cases prove more economical than cyanidation?

5. Does flotation appear to-day in any sense a competitor of cyanidation in the treatment of gold and silver ores, or will it prove a valuable accessory process?

J. M. Callow thought that at Cobalt and Goldfield flotation may replace

[1] *Min. Sci. Press*, **112**, 301 (1916).
[2] *Min. Sci. Press*, **108**, 770 (1914).

cyanidation. In some cases, where smelting and freight facilities are good, flotation may entirely replace cyanide, in others, cyanide will supplement flotation by treating concentrate. R. W. French regards flotation as an accessory process and not a competitor of cyanidation. Philip Argall thinks that flotation will undoubtedly prove a valuable accessory in many cyanide plants. E. L. Oliver says that as flotation products are of such radically different natures a general reply is not possible. So far, flotation has not been a serious competitor of cyanidation, but is already a valuable accessory, and may in time eliminate 50 per cent. of cyanide plants. Walter Neal thinks that flotation is most decidedly a competitor, but a combination process will be evolved. H. E. Wood says that flotation is a competitor in some cases, but not to an alarming extent. It is a valuable accessory process. C. W. Merrill considered that: (1) oil-flotation products are not as readily cyanided as similar products from wet concentration; (2) in special cases a combination of flotation and smelting may prove more economical than cyanidation; and (3) flotation will prove a valuable accessory process to cyaniding within the next few years. Bernard MacDonald answered that within certain limits flotation will be a strong competitor, and as an accessory to cyanidation will doubtless have a field. T. B. Crowe said that: (1) flotation products are as readily cyanided as those from other concentration methods; (2) roasting would remove the oil coating on concentrate; (3) flotation and smelting may prove better than cyanidation; and (4) flotation is a competitor, but has not been made an accessory process. C. A. Chase considers flotation a competitor. C. E. Locke says that flotation is to be a valuable adjunct to cyaniding at Cobalt.

Gold-copper ore from the Florence-Goldfield mine, Nevada, was treated successfully by flotation for a while in 1916, but owing to the low value, work was suspended. H. B. Clapp described the plant.[1] Flotation made local treatment possible, as this ore was previously shipped to smelters. The average recovery by flotation was 90 per cent. The 180-ton plant included a gyratory crusher, ball mill, trommel screen, Dorr classifier, ball tube mill, Jones-Belmont flotation machine, Janney flotation machines, Dorr thickeners, and Oliver filter.

Ores of San Juan County, Colorado, are complex, and contain in the same vein, with gold and silver, sulphides of lead, zinc, copper, and iron, according[2] to Etienne A. Ritter. In the past there has been a large loss of the precious and base metals due to poor treatment methods. Most of the production to-day is in the form of concentrate. Around Silverton the gold and silver are free from base minerals, in such mines

[1] *Min. Sci. Press*, **113**, 628 (1916).
[2] *Min. Eng. World*, **44**, 109 (1916).

as the Gold King, Iowa, and Buffalo Boy. Milling consists of either gravity concentration or flotation. Mr. Ritter describes the Gold King, Mears-Wilfley, Iowa, Contention, Hamlet, Silver Ledge, and Sunnyside mills, in which flotation is a feature, and has increased the recovery considerably. The Mears-Wilfley plant treats old tailing from the Silver Lake mill. Thus another district extracts more precious metals by the use of flotation.

The "confession of a cyanider, not that of a flotation expert," is given by Jackson A. Pearce of Idaho Springs, Colo., in his "flotation tribulations."[1] The district produces gold and silver with the common base metals. At the Argo mill flotation was tried with peculiar results for a time. At present the process for treating a gold-silver ore with small amounts of copper, lead, and zinc, is grinding through 60-mesh and concentrating, using 15 per cent. wood-creosote and 85 per cent. Wyoming gas-oil for flotation. The recovery is 97.35 per cent. of the gold, 82.2 per cent. of the silver, 93.4 per cent. of the copper, and 95 per cent. of the lead. Although higher than by cyanidation, the silver extraction is unsatisfactorily low. Cyanidation was ultimately abandoned. Practically the same article appeared in another journal,[2] various theories and vagaries of flotation being discussed.

To watch the influence of flotation oils on cyanide, J. E. Clennell[3] used a 0.24 per cent. KCN solution without alkali and six different oils. The mixtures were agitated and filtered, the filtrate showing practically no consumption of cyanide in any case.

At the Oneida mill, at Freeland, Colo., the gold and silver was contained in pyrite, gray copper, chalcopyrite, and a little galena. The process was concentration of all the pulp, followed by cyanidation of the slime. This gave a 92 per cent. recovery, according to R. W. Smith.[4] The cost of cyaniding was 80 cts. per ton of ore, the slime requiring this treatment being only 20 tons out of the original 50. The system was not economical. After thorough testing, the cyanide plant was replaced by a flotation plant. The accompanying flow sheets show the changes made. This installation cost $2000, but there was a reduction of 45 cts. per ton in treatment charges, in this case profit. Previously the company barely paid expenses. Concentrate from both processes was sold to smelters.

In his report for the year ended June 30, 1916, Hugh Rose, general manager of the Santa Gertrudis Co. of Pachuca, Mexico, said: "Experimental work was carried ahead with some very encouraging results. Cast-iron balls, in place of mine rock as a grinding medium, were tried out

[1] *Min. Sci. Press*, **113**, 427 (1916).
[2] *Met. Chem. Eng.*, **14**, 706 (1916).
[3] *Min. Sci. Press*, **112**, 700 (1916).
[4] *Eng. Min. Jour.*, **101**, 142 (1916).

in a tube mill, showing important advantages which remain to be checked by further testing. Flotation experiments were carried out in much detail in the laboratory, and the results obtained warranted the construction of two working-size machines with incidental equipment; tests on a considerable scale are now in hand. While by no means certain, it is possible that flotation may partly or even wholly replace cyanidation, at considerable saving in the cost of treatment." The ore in this mine contains 0.06 oz. of gold and 12.25 oz. of silver per ton.

Paul W. Avery discusses[1] the cyanidation of flotation concentrate when he was in Lower California. The ore assayed 0.16 oz. gold and 0.25 oz. silver. Concentrate from a small M. S. machine contained 1 oz. gold, which, when ground to 200-mesh and treated with 0.11 per cent. cyanide solution with lime and lead acetate, gave 97 per cent. recovery in 91 hr.; but the consumption of cyanide was 20 lb. and lime 40 lb. per ton of ore. This was due to the presence of flotation oil, although under 1 lb. per ton was used. Caustic soda was tried in another test to remove the oil, with much better results. A light calcination of the concentrate would drive off the excess of volatile oils that might act as cyanicides. A combination of oil, alkali, cyanide, and zinc caused trouble in the precipitation end, therefore such a mixture must not be allowed to form. H. R. Layng considered[2] that the great difference in the amount of cyanide consumed in the tests is perhaps not due to the oil being a cyanicide, but to a cyanicide, such as a ferrous salt, contained in the concentrate.

Cyaniding gold-silver concentrate from flotation plants has caused a good deal of investigation and discussion, and A. E. Drucker[3] wrote on machinery for this treatment. Flotation will be a remedy to improve concentration by saving the fine mineral of sulphide ores. In a plant employing sand tables and slime-flotation cells there would be obtained coarse concentrate that required fine grinding with cyanide solution in a tube mill, and very fine flotation concentrate not requiring grinding before cyanide treatment. The first product may be dealt with thus without preliminary treatment, but the flotation product should be cleaned of all insoluble oil before cyanidation. Mr. Drucker then analyzes grinding machinery, classifiers, pumps and elevators, agitators, thickeners, filter-presses, clarifiers, precipitation, recoveries and costs. The accompanying flow sheet shows the scheme of treatment suggested. Mr. G. F. Söhnlein of Bolivia disagreed[4] with some of Mr. Drucker's arguments.

[1] *Min. Sci. Press*, **112**, 661 (1916).
[2] *Min. Sci. Press*, **112**, 813 (1916).
[3] *Min. Sci. Press*, **112**, 517 (1916).
[4] *Min. Sci. Press*, **112**, 929 (1916).

GRAPHITE

By Benjamin L. Miller

On account of the war abnormal conditions prevailed in the graphite industry during 1916. Production was greatly increased, prices were higher than in 1915, and everywhere the industry flourished. The excessive demand for graphite was largely due to the great quantities of crucible steel and brass required by the warring nations and graphite crucible manufacturers experienced great difficulty in securing supplies of suitable material even at the prevailing high prices. The crucibles manufactured were also inferior due to the necessity of substituting other clays for the famous Klingenburg clay of Germany which has long been regarded as the standard material for graphite crucibles. It is doubtful whether the graphite crucibles made during 1916 on an average were able to stand more than half as many heats as those made before the war. In fact some users state that the crucibles which they are now using will only last about one-fourth as long as those formerly made with Klingenburg clay. Accordingly even with the same production of crucible steel and brass a much greater supply of graphite would be required.

Experiments have been made with many different kinds of clays and in the United States fairly satisfactory results have been obtained through the use of a mixture of clays found in Missouri, Illinois, and western Pennsylvania.

The international character of the graphite industry is well shown in the crucible trade in which Germany has the most satisfactory kind of clay but lacks suitable graphite, while Great Britain controls the Ceylon graphite which is not equalled by any other material for the manufacture of crucibles. The efforts which Germany has made to obtain Ceylon graphite through Holland furnishes proof that that of Passau, Bavaria, is not a satisfactory substitute for the Ceylon product.

The prices of graphite during 1916 were in many cases more than double those prevailing before the war. The unusual demand was the chief cause of the increase in price, but added to that was the increased cost of labor and the excessively high costs of transportation, especially ocean transportation. At times, ships could not be obtained for months at any price. As the cost of shipping a ton of low-grade material is the same as for a ton of high-grade product, the result has been to make an increased demand for the better varieties and little sale for the poorer grades.

The unusual prosperity of the graphite mining industry has resulted in boom conditions in many places and already the question of the future is being discussed. One writer has described the situation in Alabama as follows: "In normal times Clay County graphite has been a drug on the market. The reason for this condition was that there has never been any uniformity either in the quantity or quality of the finished flake. The buyers know this from bitter experience and do not buy Alabama graphite if they can get another class.

"Shipments of flake graphite in the past have varied between 70 per cent. and 90 per cent., but seldom reach the latter figure. The inevitable result has been a loss of customers, but just now almost any grade can be sold on account of the shortage in the supply. As soon as the abnormal demand subsides graphite will again sell only on merit. The operators are finally realizing this fact and are taking steps to supply a standard product. If the buyers can be satisfied that a standard high-grade and regular supply can be obtained from Alabama, the chances are strongly in favor of their continuing to purchase from there after the war is over, for if properly cleaned there is no better flake to be had."[1]

Graphite Production in the United States

Graphite mining in the United States was more energetically prosecuted during 1916 than in any previous year. However, this increased activity affected only a few of the many States in which graphite deposits have been worked or are known to occur.

Alabama. (By William F. Prouty).—The capacity of the Alabama flake graphite mills for the year 1916 was about 35 per cent. greater than for the previous year when Alabama furnished 49.02 per cent. of the value of the flake graphite production of the United States. The companies producing during 1916 were: Alabama Graphite Co., Clay County Graphite Co., Flaketown Graphite Co., Jennings Graphite Co., Quenelda Graphite Co., Southern Graphite Co.

By the end of 1916 the Celon Graphite Co., had completed its mill and begun operations. Two other plants were also about ready for production at the end of the year: the Crucible Flake Graphite Co. and the Lineville Graphite Co. The following plants were also under construction: Acme Graphite Co., Axton-Nowe Graphite Co., Eagle Graphite Co., Goodwater Graphite Co., May Brothers Graphite Co., Griesemer Graphite Co., National Graphite Co., Peerless Flake Graphite Co., Southern Star Graphite Co., Great Southern Graphite Co.

[1] Irving Herr, *Eng. Min. Jour.*, **103**, 694 (1917).

The flake graphite deposits of Alabama (the only kind of deposits now worked in the State) occur in a long narrow belt of two well-marked divisions, extending in a northeast-southwest direction in Clay, Coosa and Chilton Counties, with a length of about 60 miles and a maximum width of about 4 miles. The deposit covers an area of approximately 175 square miles.

The rock in which the flake graphite occurs is a mica schist, in places much intruded by both basic and acid igneous rocks. Near the large basic rock masses garnets usually occur in abundance and near the acid igneous rock areas mica is as a rule more plentiful.

The number of graphite beds varies greatly in different parts of the field. In portions of the area there are probably more than 15 distinct parallel graphite leads. In some parts of the field the beds are well developed and continuous, but elsewhere the beds change greatly in thickness and mineral content in short distances along the strike.

The ore as mined is much weathered and is quarried entirely from the open pit. The beds which are worked at the present time vary in width from 20 to more than 100 ft. In the wider beds there are usually "lean streaks." Weathering takes place to a depth varying from 40 to 100 ft., depending upon local conditions of the rock and the ground water. Quarrying is done in the weathered portion only. The less weathered "blue rock" is much more difficult to quarry and frequently contains considerable pyrite.

Most of the ore mined in the graphite region does not analyze over 3.5 per cent. graphite. The concentrates from most of the mills run about 60 per cent. carbon and the No. 1 flake ranges from 85 to 95 per cent. carbon.

The question is often asked as to the possibility of profitable extraction of graphite in this field during normal times. This question can best be answered by consulting the figures of costs and earnings of one of the plants of the Alabama region, of average efficiency, for the year 1913 (before war-time prices). This plant, with total cost including land and quarries of about $35,000, produced graphite during the above year to the value of $59,883.55 at a cost, including operating expenses, renewals and extensions in equipment, of $31,091.82, leaving a net profit of $28,791.73. The average prices received for the graphite shown in the above production were:

For No. 1 crucible flake	6.5 cts.
For No. 2 lubricating flake	4.5 cts.
Dust	1.5 cts.

During 1916 the price of Alabama flake graphite was practically twice that for 1913.

Taking the graphite ore from the open pits is a comparatively simple and inexpensive process. The average cost of quarrying and transporting to mill is about 17 cts. per ton. Occasional shots are necessary to loosen the rock, but pick and shovel, quarry bar and sledge are largely employed in getting out the rock and reducing it to sizes suitable for the crushers. It is of great advantage to open the quarry in such places as to avoid excessive stripping and the condition of an overhanging wall. Beds which are vertical or nearly so, or which have a dip direction with the slope of the hill, offer the most nearly ideal conditions.

There are several methods employed in the Alabama field at the present time for the reduction of the ore and its separation. Most of the processes are comparatively new, and have not yet been perfected. In the reduction of the ore the processes which bring about a gradual reduction in the size of the ore and give the least rubbing of the ore give the best results by yielding a higher percentage of No. 1 flake and less dust. A gradual reduction by the use of several sets of rolls is coming more into favor.

At the present time most of the mills are employing the wet process of separation by flotation, and all but one of these are using water without oil. The dry method of separation has proven successful for certain parts of the field, and will doubtless be more used as an auxiliary in the mills using the wet process as time goes on. The electrostatic process for the separation of mica and graphite has also proven locally successful, and with certain changes in the character of the machine to adapt it to local differences of ore could probably be used successfully. It is difficult to tell which of the various processes gives the best results. There is a wide difference at the present time among those using approximately the same method of separation in the percentages of graphite recovered. The efficiency of the washers, for instance, depends on various factors; the dimensions, the rate of flow of the water, the evenness or rate of feed, the conditions of the ore, the angle at which the ore hits the water, the character of the ripples, etc. The best results are obtained by those who have the most scientifically constructed washers, and who are able to adapt the washers or other separating machinery to the local conditions.

In the flotation process a large amount of water is required, so that the location of the plant using that process must be near a permanent water supply. The location of the dry-process mill is, of course, on this account less restricted, and many good locations, as far as mill site and ore supply are concerned, could be had where it would not be possible, or at least profitable, to operate a water-separation mill. Since only about 3 per cent. of the graphite ore is graphite, practically the entire bulk of the rock quarried must be disposed of, so that sufficient land must be purchased on which to settle the "sand" which comes from the washer. This is no small consideration for a large capacity mill with downstream neighbors. In a number of the wet-process mills the water is ponded and used again and again during the dry season, but even with this precaution the amount of water consumed is relatively large, and the minimum water supply is an important consideration in the location of a plant.

In all the plants now operating in the field the ore is dried in wood-heated kilns and necessitates a considerable amount of timber for such purposes.

The nearness to rail of the graphite plants has less to do with their profitable operation than does a good grade of ore and other favorable circumstances, since the weight of the graphite mined is inconsiderable in respect to its value, and since cheap electrical power can be had in most parts of the field. Some of the mills are as much as 8 miles from the end of the Ashland branch railroad.

The amount of graphite recovered from the ore varies greatly at different plants; estimates vary from 50 to 80 per cent.

Montana.—The graphite deposit near Dillon, Mont., was worked during 1916. The difficulties of transportation and also the fact that the material can not be milled satisfactorily greatly interfere with the development of this property.

New York.—Although New York no longer holds first place in the production of graphite the industry is nevertheless of great importance. In the following paragraphs Robert W. Jones[1] discusses the different kinds of graphite deposits found in the State and their distribution.

There are several grades of ore found in the Adirondack region. Graphite is found in veins, in metamorphosed sediments and in the igneous rocks. It is probable that the early output was made from vein material, as this showed as a coarser crystalline flake and attracted the attention of the early prospector. The output from the igneous rocks has not been very great. The metamorphosed limestones have made some output, although the milling returns from this class of ore have not been so great as was expected. This ore is deceiving. In hand specimens and in carload lots it appears as a high-grade ore. The flakes are large, some of them reaching a diameter of over 1½ in., but in milling it is found that the percentage of good flake is not high. Samples taken from what has been milling ore have seldom yielded, even in picked specimens, more than 3 per cent. Of this amount about one-third will have a diameter of ¼ in. or more. The rest will average a little larger than 1/16 in. One great difficulty in the milling of limestone ores is caused by the large amount of heavy minerals present of such size that it is

[1] *Eng. Min. Jour.*, **102**, 774–775 (1916).

necessary to crush fine in order to liberate the graphite, which is completely surrounded by or intermeshed with the other minerals in most cases. Outcrops of these ores occur at Kings Station, Chilson Lake, Ironville and Crab Pond.

The igneous rocks, which in most cases are pegmatites, yield a product somewhat like that from the limestones, except that the flakes are crowded together into thicker bundles. The mill return is about the same as from the limestones. This thickening of the plates makes a product for which there is not the demand that there is for the smaller free flake. While in most cases the pegmatites are more brittle than the limestones, yet with the presence of graphite the toughness of the rock is increased, making it more difficult to produce a commercial flake. No attempt has been made to work the igneous deposits on a commercial scale. These ores are exposed at Breeds Hill, Spuyten Duyvil Creek Valley and Crab Pond.

The metamorphosed sandstones and shales are responsible for the entire commercial production of graphite from this district at present. These deposits are found throughout the graphite-producing area in great abundance, although not all of commercial value. Owing to the banded nature of the rock, milling is comparatively simple, although the presence of mica offers some difficulties to economical separation. The thickness of these deposits varies from a few feet to as much as 40 ft. with outcrops several miles in extent. Feldspar, being one of the main rock minerals, has in almost all the outcrops disintegrated to such an extent that the surface ore can be mined easily. This disintegration is due to the presence of sulphides. Pyrite and chalcopyrite are found throughout the ore in lens-shaped masses, having in some localities a thickness of as much as 2 in. and covering an area 4 or 5 in. square. At one locality an attempt has been made to save the chalcopyrite. The graphite content of the ore varies, reaching in a few exposures as high as 10 per cent. The average is about 5 per cent. figured on the recovery from the mill. Prominent exposures of this class of ore are found at Rock Pond, Bear Pond, Spuyten Duyvil Creek Valley, Graphite, Porterville, Kings Station and North Pond. These ores also outcrop between Lake Champlain and Lake George, west and northwest of Whitehall and extending as far north as Putnam Corners. Although it has high-grade ore in many localities, the Whitehall district has never made a success in the production of graphite.

Conditions During 1916. (By D. H. Newland).—The unusual conditions which have obtained recently in the graphite trade were reflected to some extent in the mining industry in 1916, but perhaps not to the extent that would have been expected. The output in fact was only an average one, and there was no addition to the list of contributing mines from that of the preceding year which included the American mine at Graphite, Warren County, the mine of the Saratoga Graphite Products Corporation, Saratoga County, and the mine near Popes Mills, St. Lawrence County. Developments were in progress that will, doubtless, result in an important gain of production during the current season. Of these may be noted the enlargement of the mine and milling facilities by the Saratoga Graphite Products Corporation and the opening of a new deposit near Whitehall by Hooper Bros., perhaps the most promising enterprise that has been started in the Adirondack region in view of the experienced men in charge of it and the favorable natural conditions on the property for the conduct of mining and milling operations. The occurrence belongs to the prevalent Adirondack type, that is, a quartzite carrying disseminated flake graphite which represents one of the members of the early Precambrian (Grenville) formations of that region. The body is unusually thick—about 40 ft. altogether—and outcrops along the side of a ridge, having little or no cover of soil over much of it, so that it can be readily and very cheaply worked as a quarry. The flake is of good size and measurably free from intergrowths with mica, both of which features have an important bearing upon the quality of the final products obtained in the milling operations. The carbon content ranges up to 15 per cent., the richest part of the deposit comprising a 14-ft. seam in the middle of the section. The length of outcrop is nearly ¾ mile. The development work which was begun in the fall of 1916 was continued throughout the winter with a view to the starting of productive operations in the early part of the current year.

Pennsylvania.—The high prices that prevailed during 1916 stimulated activity in the graphite region of the State and resulted in the re-opening of several properties that had long been idle. The production for the year greatly exceeds that of any year for some time past, with promise of a still greater production during 1917.

Five graphite companies were in operation in Chester County during 1916. The Graphite Products Co. operating the old Pennsylvania mine near Byers was the largest producer. Adjoining this property the Tonkin Graphite Co. operated the Pettinos Bros. mine under lease and erected a small mill for experimental purposes with the intention of enlarging it later. Near Chester Springs, the Rock Graphite Co. opened a small mine and built a concentrating mill on the Rohrbach Farm. From the latter plant the concentrates were hauled to the refining mill at Byers, once owned by the United States Graphite Co. Near Pikeland the Standard Carbon Co. was also in operation during part of the year.

Rhode Island.—The amorphous graphite deposits of Providence, R. I., were worked during 1916 to obtain material for foundry facings. These deposits consist of greatly metamorphosed beds of coal, altered to such an extent that they can not be satisfactorily used for fuel purposes. The material is, however, well adapted for foundry facings and each year a number of shipments are made. The production depends upon the demand solely, as many times the amount required could easily be produced.

Texas.—During 1916 the Texas Graphite Co. developed a graphite mine, 8 miles northwest of Burnet, Burnet County, and the Heath Graphite Co. opened a mine 5 miles northeast of Llano, Llano County. The former company built a mill while the latter utilized a mill that was built by a gold-mining company.

STATISTICS OF GRAPHITE IN THE UNITED STATES

Year.	Refined Crystalline Graphite.						Amorphous Graphite Production.	
	Production.		Imports.		Consumption. (*a*)			
	Pounds.	Value.	Pounds.	Value.	Pounds.	Value.	Tons. 2000 Lb.	Value.
1901	3,967,612	$135,914	32,029,760	$895,010	36,997,372	$1,067,921	809	$31,800
1902	4,176,824	153,147	40,857,600	1,168,554	45,034,424	1,322,401	4,739	55,964
1903	4,525,700	164,247	32,012,000	1,207,700	36,537,700	1,371,947	16,591	71,384
1904	4,357,927	162,332	25,350,000	905,581	29,707,927	1,067,913	19,115	102,925
1905	4,260,656	170,426	34,914,611	983,034	39,175,267	1,153,460	21,953	80,639
1906	4,894,483	170,866	50,974,336	1,554,212	55,868,819	1,725,098	16,853	(*b*)
1907	4,586,149	149,548	40,962,000	1,777,389	45,548,149	1,926,937	26,962	138,381
1908	3,433,039	149,763	22,912,714	762,267	26,345,753	876,030	1,433	75,250
1909	5,669,899	340,194	42,532,851	1,854,459	48,202,750	2,194,653	5,096	32,238
1910	5,625,132	286,882	50,610,560	1,872,592	56,235,692	2,159,474	1,407	39,710
1911	4,790,000	256,050	41,404,000	1,495,729	46,194,000	1,751,779	1,223	32,415
1912	3,543,771	187,689	51,286,000	1,709,337	54,829,771	1,897,026	2,063	32,894
1913	5,064,727	254,328	57,758,400	2,109,791	62,823,127	2,364,119	2,243	39,482
1914	5,220,539	285,368	44,004,800	1,398,261	49,225,339	1,683,629	1,725	38,750
1915	7,074,370	417,273	46,150,000	2,241,163	53,224,370	2,658,436	1,181	12,358
1916	10,932,000	914,748	68,816,000	7,279,884	79,748,000	8,194,632	2,622	20,723

(*a*) Neglecting the small re-export of foreign product. (*b*) Not reported.

WORLD'S PRODUCTION OF GRAPHITE
(In metric tons)

Year.	Austria.	Bavaria.	Canada.	Ceylon. (*a*)	India.	Italy.	Japan.	Mexico. (*b*)	Sweden.	United States. (*c*)	France and Colonies.
1900	33,663	9,248	1,743	19,168	1,859	9,720	94	2,561	84	1,799	....
1901	29,992	4,435	2,004	22,707	2,530	10,313	88	762	56	1,800	....
1902	29,527	5,023	993	25,593	4,648	9,210	97	1,434	63	1,895	....
1903	29,590	3,719	660	24,492	3,448	7,920	114	1,404	25	2,053	....
1904	28,620	3,784	410	26,478	2,955	9,765	216	970	55	2,045	....
1905	34,416	4,921	491	31,134	2,361	10,572	209	970	40	1,933	....
1906	38,117	4,055	405	36,578	2,642	10,805	177	3,915	37	2,220	....
1907	49,425	4,033	525	33,027	2,472	10,989	103	3,202	33	2,080	....
1908	44,425	4,844	227	26,227	2,919	12,914	177	1,076	66	1,557	....
1909	40,710	(*e*)4,900	783	25,995	3,182	11,583	284	1,704	26	5,875	300
1910	33,131	7,415	1,263	30,008	4,319	12,510	145	2,332	49	3,811	320
1911	41,599	11,298	1,154	27,433	4,047	12,621	114	2,974	65	3,280	1,100
1912	45,375	12,532	1,873	33,106	*Nil.*	13,170	149	2,865	79	3,318	1,870
1913	49,456	....	1,961	29,277	*Nil.*	11,145	665	1,057	88	4,331	5,600
1914	....	....	1,494	....	*Nil.*	8,567	574	....	56	3,935	(*e*)7,000
1915	....	....	2,368	....	71	6,176	666	....	87	4,280	....

(*a*) The figures for 1907, 1908, 1912 and 1913 are exports. (*b*) Exports. (*c*) Crystalline graphite up to 1909. (*e*) Estimated.

Graphite is said to be present in several places in the schists and gneisses of these two counties. In the Burnet region the graphite occurs in small flakes in a crystalline schist into which many graphite-bearing pegmatite dikes have been injected. The flakes are of good quality, mica is present only in very small amount, and quartz and soda feldspar are the principal gangue minerals. A writer in the *Mining American* describes the deposits as follows:

The graphite schist forms a band 100 to 200 ft. wide that is traceable almost continuously for about 4000 ft. Careful sampling of the western 1400 ft. of the deposit by an engineer employed by the company showed that the rock contains 10.3 per cent. of graphite. The samples assayed weighed in all 11,000 lb., and in determining the percentage of graphite the higher assays were excluded. Within the commoner type of light-gray graphite schist there are a number of large lens-shaped bodies of dark-gray schist in which graphite is notably more abundant and forms larger flakes. Though the flakes of graphite are on the average smaller than those in the Alabama deposits, a preliminary examination indicates that the deposit will yield a fair proportion of flakes that are large enough to be used for making crucibles.

Graphite in Foreign Countries

Australia.—Some graphite deposits on the Donnelly River, 15 miles east of the Manjimut railway station and 80 miles from the port of Bunbury, West Australia, have been investigated by H. P. Woodward, Assistant Government Geologist. Numerous attempts have been made to work them during the past 30 years, but without success. Mr. Woodward's conclusion is that the graphite is too pale in tone to be of any value for pencil making, and contains too high a percentage of earthy matter for lubricants; therefore the only purposes to which the highest class portions of this deposit might be put at the present time are the manufacture of low-grade graphite paints and possibly fire-bricks. He further states that while the deposits are of considerable extent and size, the material so far exposed is of little or no commercial value owing to its physical character, and the only value attaching to the deposits is prospective. Since, however, there is every possibility that a change of character for the better of this material will take place at a moderate depth, they are well worthy of further exploitation, which owing to the great regularity and size of the seams could be cheaply and satisfactorily performed by boring.[1]

Brazil.—Graphite is known to exist in several places in the old gneisses and schists of eastern Brazil, but as yet only small amounts have been mined. Samples of good quality have been sent to the United States

[1] *Min. Eng. Rev.*, Dec. 5, 1916.

while one small commercial shipment has been made. The deposits seem to merit further investigation.

Canada.—The graphite deposits of Ontario and Quebec were actively worked during 1916 under the stimulus of the high prices prevailing. The production was about 50 per cent. greater than in the previous year with the value more than twice as much. The principal producers were the Dominion Graphite Co. and the Quebec Graphite Co. of Buckingham, the Black Donald Graphite Co. of Calabogie, and the Globe Refining Co. of Port Elmsley.

The following statement has been issued by the Department of Mines in the Preliminary Report of the Mineral Production of Canada for 1916.

The total shipments of milled and refined graphite were 3971 tons, valued at $285,362, or an average of $71.86 per ton, and included 495 tons, valued at $35,776 from Quebec, and 3476 tons, valued at $249,586 from Ontario.

The production includes material varying in value from $54 to $270 per ton.

The production in 1915 was 2635 tons, valued at $124,223.

Exports of plumbago, crude and concentrates, were reported as 311 tons, valued at $13,114, and of manufactures of plumbago to the value of $304,919.

Ceylon.—The production of graphite during 1916 was hindered considerably by the lack of shipping facilities. It was impossible for many of the crucible manufacturers to obtain as much Ceylon graphite as they desired even at the increased prices they were willing to give and other kinds of graphite entered into crucible manufacture to a larger degree than in any previous year. Even with sufficient shipping available it is doubtful whether the mines of Ceylon are capable of a greatly increased production because of increasing depth and consequent difficulty to care for the water encountered.

On July 24, 1916, the following prices were quoted in Colombo:

	Per Ton.
Large and ordinary lumps	$129.75 to $438.00
Chips	97.35 to 308.20
Dust	24.35 to 113.55
Flying dust	13.00 to 64.90

The New York prices were about as follows during 1916:

	Per Pound.
No. 1 lump	26 to 28 cts.
No. 1 chip	19 to 20 cts.
No. 1 dust	10½ to 12 cts.

Throughout the year the demand for the cheaper grades was not great because of the high freight charges. It costs as much to ship a barrel of the dust or chip as a barrel of the lump so that the higher grades mainly were sought. In some cases the transportation cost more than the graphite.

Chosen (Korea).—Considerable amorphous and some crystalline flake graphite came from Chosen (Korea) during 1916. Instead of coming to New York by way of the Panama Canal as formerly, some shipments were landed in Seattle and San Francisco during the time that the Canal was closed. The price obtained varied from $45 to $55 a ton.

Germany.—When the war started Germany is supposed to have had large supplies of Ceylon graphite on hand. These, however, were long ago exhausted and the crucible manufacturers have had to rely upon the deposits of Passau, Bavaria, where less satisfactory material has long been obtained. The situation is well described in the following brief report from the U. S. Consul at Munich under date of Jan. 26, 1917.

A lecture on the Bavarian graphite industry was delivered recently by Prof. Heinrich Putz before the Polytechnic Society. It was printed in the *Münchner Neueste Nachrichten.* As translated, the speaker's views relate especially to the effect of the war on the industry. "Our graphite," he said, "has gained unusual importance because we are cut off from the sea and the supply of Ceylon graphite. The scaly Bavarian or 'Flinsgraphite' has from time immemorial been used for crucibles for melting metal. Until the discovery of the Ceylon graphite deposits, Obernzell, in Bavaria, supplied all Europe with crucibles, without competition." In showing what had been done in the past few years, he said:

"In order to compete with the over-sea graphite, which produced better crucibles, it was necessary to refine the Bavarian Flinsgraphite by removing the accompanying minerals found in graphite-gneiss (the minerals as taken from the deposits). To meet competition I endeavored as early as 1885–86 to further improve the quality of the Bavarian graphite by a better method of refining. Later on, in 1901, I set myself the task of artificially transforming the Bavarian graphite, which is for the greater part composed of small particles, to large particles and lumpy graphite, similar to the Ceylon product, as, according to experience, upon that depends the good quality of the crucibles, which do not crack in fire. The discovery of plasticity made by me was of assistance in this connection. The small particles can be compressed into large lumps by pressure.

"Another problem still to be solved by the Bavarian graphite industry is how to avoid the loss sustained by cleansing, which amounts to about 25 per cent. of the quantity to be gained.

"In the association's plant the problem of utilizing all graphite found in Bavaria was solved, but owing to the dissolution of the association other works could not be made acquainted with it.

"A notable event in the field of graphite utilization in Bavaria was the establishing of the first German refined-graphite laboratory for machine lubrication."

Madagascar.—The great demand for graphite occasioned by the increased use of crucible steel and brass in war munitions resulted in the largest production of Madagascar graphite in 1916 in the entire history of the industry. The French Government felt obliged to call upon the graphite producers of the island to increase their output because of the urgent demand for the material with the result that the necessities have been fully met.

Although the embargo placed upon Madagascar graphite was lifted during 1916 it has still been difficult to obtain the material on account of the lack of shipping facilities. The French Government has used the bulk of the production. All graphite sold to foreign customers is supposed to go to Marseilles and the buyers have experienced many delays in obtaining the product. A few shipments by special authorization were made directly to the Morgan Crucible Co. of London.

Mexico.—Notwithstanding the unsettled conditions prevailing in Mexico during 1916 considerable amorphous graphite was obtained there by the United States Graphite Co. This material has long been considered the best graphite known for pencils. It is a coal bed that has been metamorphosed to graphite by the intrusion of igneous dikes.

The ore is hauled by teams 20 miles to the railroad station of Torres in the State of Sonora and thence shipped to the offices of the company at Saginaw, Mich.

Rhodesia.—Several deposits of graphite are known to occur in the Territory of Rhodesia, some of which seem to be of large size. While the material is of too low grade to be exported it is hoped that it can be used locally as a substitute for imported graphite. Tests have been made with a view to producing a dry flake graphite and a graphite paste or antifriction grease.

Manufactured or Artificial Graphite

The International Acheson Graphite Co. of Niagara Falls, N. Y., has continued to increase its production in order to keep pace with the demand for its products. The manufactured graphite, although suitable for many purposes, can not be used for all the purposes for which the natural graphite is utilized. The increase of electric furnaces and other new applications of electricity, has aided the industry of manufactured graphite. A new plant is to be built at Buffalo in order to still further increase the output.

PRODUCTION OF MANUFACTURED GRAPHITE 1899–1916

Year.	Quantity, Lb.	Value.	Price per Pound, Cents.
1899	405,870	$32,475	8.00
1900	860,750	68,860	8.00
1901	2,500,000	119,000	4.76
1902	2,358,828	110,700	4.69
1903	2,620,000	178,670	6.82
1904	3,248,000	217,000	6.70
1905	4,595,500	313,979	6.83
1906	4,868,000	312,764	6.42
1907	6,924,000	483,717	6.97
1908	7,385,511	502,667	6.80
1909	6,870,529	467,196	6.80
1910	13,149,000	945,000	7.19
1911	10,144,000	664,000	6.54
1912	12,896,347	830,193	6.44
1913	13,633,342	973,397	7.14
1914	10,455,139	698,800	6.68
1915	(a)5,580,437	109,102	1.96
1916	(a)8,922,329	....	....

(a) Powdered graphite only; electrode material not included.

GYPSUM

By F. A. Wilder

The year 1916 was a prosperous one for the gypsum industry of the United States as a whole. For a few of the mills, however, the year was one of depression. These were mills dependent on Nova Scotia and New Brunswick for their supply of crude mineral, and dependent also on securing favorable charters of coastwise shipping for transporting the mineral. Such charters were not to be had in 1916 and as a consequence a number of mills in and about New York City were practically closed down. Additional tonnage was thrown to the mills owning their own boat lines, but as statistics for Canadian production presented later show, imports of Canadian gypsum were considerably reduced. The mills in Western New York were called on for a much larger output and shipped more freely than usual into New York City and Eastern Pennsylvania. The output of Virginia mills likewise was favorably affected by the elimination of coastwise competition.

Production costs for the year were high, due to the high cost of explosives, hair, burlap, and labor. Selling prices were considerably higher in consequence.

The demand for crude gypsum from cement mills was well sustained throughout the year.

The use of ground gypsum as fertilizer, and particularly as a preservative in connection with manures, is growing and there is reason to believe that the demand for gypsum in agriculture may again become important.

The main demand for gypsum was, as usual, in the form of wall plaster. The year was one of marked building activity and the output of wall plaster kept pace with the increase in building permits.

The use of calcined gypsum for flooring and roofing increased considerably during the year. Larger recognition was given to gypsum blocks and plaster board by the Underwriters' Laboratories. Various types of gypsum roof construction received favorable consideration at the hands of engineers and have made a permanent place for themselves on account of their lightness and their non-conductivity. A most important and authoritative report on gypsum roof construction appears in *Bulletin* No. 25, Public Works of the Navy (Jan., 1917).

While ordinary calcined plaster is being developed for flooring purposes, no flooring (or Estrich) gypsum, burned at high temperature, after the manner in vogue in Germany, is being prepared in the United States.

CRUDE GYPSUM MINED IN THE UNITED STATES (a)
(Tons of 2000 lb.)

1881	85,000	1893	253,615	1905	1,043,202
1882	100,000	1894	239,312	1906	1,540,585
1883	90,000	1895	265,503	1907	1,751,748
1884	90,000	1896	224,254	1908	1,721,829
1885	90,405	1897	288,982	1909	2,252,785
1886	95,250	1898	291,638	1910	2,379,057
1887	95,000	1899	486,235	1911	2,323,970
1888	110,000	1900	594,462	1912	2,500,757
1889	267,769	1901	633,791	1913	2,599,506
1890	182,995	1902	816,478	1914	2,476,465
1891	208,126	1903	1,041,704	1915	2,447,611
1892	256,259	1904	940,917	1916	2,756,630

(a) Statistics of the U. S. Geol. Surv.

The total value of crude and calcined gypsum marketed in 1916 was $7,952,432 as compared with $6,596,893 in 1915. This is the first time that the value of the output has exceeded $7,000,000. In 1916, as in former years, New York was the largest producer of raw gypsum, Iowa ranked second, and Michigan third. The output of these States was as follows:[1]

GYPSUM MINED AND MARKETED IN THE LEADING STATES IN 1916

State.	Quantity Mined (Short Tons).	Sold as Calcined Plaster (Short Tons).	Total Value.
New York	579,827	311,264	$1,459,587
Iowa	522,293	373,416	1,496,795
Michigan	457,375	292,109	1,066,599

Although Iowa stood second in quantity of raw material mined, it took first place in value of finished product, as it did in 1915, because a much larger proportion of the gypsum produced in New York is sold uncalcined to Portland cement plants.

Among the notable increases in the use of gypsum in 1916 was that shown by the larger quantity sold for land plaster, the sales being 81,879 tons as compared with 69,256 tons in 1915. The average price per ton for all calcined plasters jumped from $3.68 in 1915 to $3.97 in 1916.

New York (By D. H. Newland).—There were no important changes in the gypsum industry last year, and the list of active mines was practically the same as in 1915 with production on about the usual scale. The output in terms of crude rock recently has averaged a little more than 500,000 tons a year. About two-thirds of the yield is utilized at the mines

[1] U. S. Geol. Surv. *Press Bull.*

for calcining, and one-third or a little less is shipped in crushed or ground form to Portland cement manufacturers and for land plaster. The calcining business is centered in the western part of the district of Monroe, Genesee and Erie counties, where the gypsum—although found amid similar geological surroundings—is lighter in color and higher in calcium sulphate than the rock in the eastern sections. The other counties that have been productive recently include Onondaga and Cayuga which yield a lower grade product, suitable, however, for agricultural and cement manufacturing purposes.

One important feature that has come to light in regard to the distribution of the gypsum in New York is that the better quality of rock occurs in rather limited areas, even within the western section. Apparently, the deposits have a lenticular form, rather than that of a more or less continuous sheet or stratum, and the successive lenses may be separated by areas within which the gypsum occurs only in thin seams —too small to be of commercial importance. The distance between successive workable lenses is often considerable. This fact has been brought out by drilling along the outcrop which has failed oftentimes to reveal deposits when the conditions seemed most favorable for their occurrence. It is not unlikely that solution by underground waters has had something to do with the patchy distribution of the material; on the other hand, there is no ground for assuming that the deposits were originally continuous throughout the stretch of the Salina formation. On the western end of the field the beds at most are only 5 to 6 ft. thick

PRODUCTION OF CRUDE GYPSUM IN THE PRINCIPAL COUNTRIES (*a*)
(In metric tons)

Year.	Algeria. (*b*)	Canada.	France. (*b*)	Germany. (*c*)		Greece.	India.	United Kingdom.	United States.
				Baden.	Bavaria.				
1899	39,950	221,821	1,807,454	29,419	29,727	81	6,546	215,974	382,891
1900	42,237	228,656	1,774,492	26,381	35,484	129	4,415	211,436	439,265
1901	44,025	266,476	2,385,633	28,183	3,581	671	(*d*)	204,045	598,529
1902	44,975	301,165	2,185,346	33,150	31,701	*Nil.*	(*d*)	228,264	740,906
1903	41,550	285,242	1,998,804	29,423	30,894	94	(*d*)	223,426	945,285
1904	48,375	309,133	1,957,802	26,984	22,766	393	3,937	237,749	853,546
1905	34,743	395,341	1,378,145	28,823	46,247	185	4,877	259,596	982,626
1906	27,950	378,904	1,377,429	25,643	50,763	70	(*e*) 5,000	228,627	1,397,480
1907	26,400	431,286	1,316,567	29,153	48,975	70	(*e*) 5,000	239,285	1,564,061
1908	25,500	346,436	1,750,562	35,217	51,314	*Nil.*	(*e*) 5,000	231,980	1,694,155
1909	36,250	398,290	1,655,672	36,621	51,630	191	17,588	242,832	*f*)2,042,286
1910	60,625	481,941	1,980,804	41,078	54,397	249	13,759	259,648	*f*)2,158,756
1911	61,502	470,381	2,110,520	42,408	60,390	1,263	11,115	281,111	*f*)2,112,770
1912	(*d*)54,414	524,892	2,150,900	51,777	57,114	127	21,383	247,724	*f*)2,269,290
1913	50,413	577,442	1,726,379	49,767	....	2,245	25,362	242,341	*f*)2,357,752
1914	....	463,375	....	....	....	639	22,639	269,637	*f*)2,247,246
1915	....	430,752	....	....	....	1,648	22,926	251,209	*f*)2,220,458
1916	....	309,916	....	....	....	....	....	191,841	*f*) 2,500,815

(*a*) From official reports of the respective countries, except the statistics for the United States. (*b*) A part of the product is reported as plaster of Paris. In converting this into crude gypsum it has been assumed that the loss by calcination is 20 per cent. (*c*) Prussia is a large producer of gypsum, but there are no complete statistics available. The output in 1910 was 22,042 tons. (*d*) Statistics not available. (*e*) Estimated. (*f*) U. S. Geol. Surv.

and the superficial area of the workable portions may amount only to a few hundred acres each.

Montana.[1]—A small gypsum mill was operated for several years in southern Montana at Bridger, near Red Lodge, in Carbon County; but being several miles from a railroad it could not produce and ship plaster of paris very cheaply and has been closed for some time. Another mill was operated successfully near Armington, southeast of Great Falls, for several years on a gypsum deposit 25 to 30 ft. thick, but this mill has also been closed for several years. Near Great Falls a small mill of about 100 tons capacity has been operated for some time past, and until this summer was the only mill in operation in the State. Some gypsum has been quarried and shipped from Limespur in Jefferson County. Recently the Hanover Gypsum Co. has built a 400-ton modern plant on its property, 7 miles west of Lewiston, in central Montana, which is now the largest in the State.

Gypsum occurs in central Montana in two ways. First, as selenite crystals disseminated throughout the Black Bearpaw and Claggett shales of Cretaceous age; these crystals are of many different sizes and forms and are often twinned, and while abundant in the bad lands where erosion has carried away the shales in which they are found, are of no commercial importance. Second, as beds of gypsum rock and of disintegrated gypsum or gypsite, which are the source of the commercial products. The age of the chief gypsum beds is believed to be Jurassic and they were probably the result of evaporation of sea water, and consequent deposition of the gypsum from solution. Some gypsum beds, however, are late carboniferous, possibly in part Permian or Triassic.

The South Moccasin mountains are a small group in central Fergus County; about a mile south of them a dome uplift has occurred, probably the result of an igneous intrusion, and the overlying Cretaceous shales and sandstones have been removed by erosion, exposing the gypsum-bearing Jurassic strata. Spring creek has cut a valley through the southern part of this dome and both the Great Northern and the Chicago, Milwaukee & St. Paul railroads have here built along the north side of the valley, their tracks coming within 50 yd. of the gypsum outcrops. Spur tracks have been completed and the shipping facilities are excellent.

The Hanover Gypsum Co. owned about 1000 acres on this dome, most of which is believed to be underlain by gypsum. Gypsum outcrops a few rods from the mill. The top bed is 7 to 11 ft. thick, and has been disintegrated to form gypsite, which is either at the surface, or under slight cover, and will be worked by quarry methods. This bed is underlain by a few feet of limestone, which in turn is underlain by a bed of

[1] O. W. Freeman, *Min. Eng. World*, Oct. 14, 1916.

pure white gypsum 15 to 30 ft. thick, which will be mined, the limestone affording a good roof. Both the main quarry and the mine are about 1000 ft. from the mill, and the rock from them is loaded on the same track, which has a grade of 2½ per cent. and is carried to the mill by gravity; mining costs should then be low. A third gypsum bed underlies the others, but it has not been explored much by drilling, and will not be mined at present. In summer the gypsum will come entirely from the quarry, but in winter much of it will be mined.

In the mill the gypsum first passes into a 24 by 36-in. Ehrsam jaw crusher that has a capacity of 1 ton per min., and crushes the material to a 4-in. size. A rotary crusher of equal capacity next reduces this to a 1-in. size after which it goes to the storage bins. The crusher building is separate from the rest of the mill, and an underground conveying belt carries the crushed gypsum from the bins, first over a rotary drier and then through a cylindrical drier 6 ft. in diameter and 40 ft. long. The dried gypsum is then elevated to bins, from which it next goes to the Raymond mill, which grinds it into a fine powder. It is then lifted by a Cyclone elevator and blown into the large calcining kettles, where most of the water of crystallization is driven off, thereby changing the gypsum into stucco or plaster of paris.

Besides various manufactured plasters, made by mixing with hair or fiber, the company makes plaster board, land plaster, gypsum tile and crushed gypsum for use as a retarder in Portland cement. The mill has a present capacity of 300 to 400 tons daily, but there is room for more calcining kettles, and by their installation the capacity of the mill could be easily doubled, as the capacity of the rest of the machinery is in excess of present requirements. About 30 men are employed at the plant, which represents an investment of $150,000. The Hanover gypsum is exceptionally pure and many carloads of crude have been shipped to other companies who wish to increase the per cent. of their product.

The United States Gypsum Co. has just announced that it will immediately start work on a gypsum plant of several hundred tons daily capacity at Heath, about 10 miles east of Lewiston. Three hundred acres have been leased, which contain exceptionally pure gypsum. It is estimated that there is at least 7,000,000 tons easily available on this tract. Two miles south of Forest Grove pure thick beds of gypsum outcrop extensively. The Chicago, Milwaukee & St. Paul branch east from Lewiston passes close to both these deposits. Pure beds of gypsum over 20 ft. in thickness occur in the foothills of the Big Snowy Mountains, as on the east fork of Spring Creek, and near Irene, on the south side of the Snowies. A small amount of pure white gypsum has been produced in the foothills southeast of Moore, but practically no work has been done on any gypsum deposits near the Big Snowy Mountains. The gypsum found on the southwest side of the Snowies is exceptionally white and pure, and being found only a few miles from the railroad, might be utilized at a profit. Quantities of excellent gypsum in beds 20 to 30 ft. thick occur on Alaska Bench, east of the Snowies and near the N Ranch, northwest of Tyler. These deposits are, however, a long way from the railroad. They both appear to be of Upper Carboniferous age. Northwest of the Little Belt Mountains a great gypsum bed outcrops where Jurassic rocks occur; this bed is very thick and pure, as near Kibbey, 30 miles from Great Falls. Farther south, to the southwest of the Little Belts, the gypsum beds become thin and impure. Large deposits of gypsum also occur in eastern Montana, and north of the Missouri River near the Bearpaw Mountains and elsewhere. With such large reserves available, the manufacture of gypsum products in the near future will probably be restricted chiefly to those localities where railroads are close to the gypsum properties, the more important of which have been briefly mentioned.

South Dakota.—During 1916 the United States Gypsum Co. began the construction of a new mill at Piedmont, on the Northwestern Railroad. This mill will use as crude material both gypsum rock and gypsite.

Wyoming.—*Bulletin* 640-H, of the United States Geological Survey, describes gypsum in the southern part of the Bighorn Mountains. A number of outcrops are described in which extensive bodies of excellent gypsum occur, analyses are given and the percentage of impurity in most instances is small.

In connection with the development the *Bulletin* states:

"The gypsum in the area described in this report is known to have been utilized at only two places, both near Greybull, on the west and south flanks of Sheep Mountain. Most of the gypsum is quarried in the upper part of the Chugwater formation about ½ mile west of Stucco, a flag station on the Chicago, Burlington & Quincy Railroad. It is hauled by wagons to the railroad and shipped to Basin, about 18 miles distant. The gypsum is calcined and made into stucco blocks, which are used in building.

"The mill at Basin is of small capacity, using about 200 tons of gypsum a month. In preparing the stucco blocks the raw gypsum is crushed, pulverized and calcined. Care is taken in calcining not to overheat the pulverized gypsum, for if this is done it is said to be 'dead burned,' and the particles will not 'set' or recrystallize. In calcining the gypsum is usually heated to about 177° C. (350° F.).

"The selling price of the stucco blocks is small as compared with the price of lumber in this region. It is reported that blocks sufficient for the walls of a building 25 by 30 by 9 ft. cost about $200.

Buildings made of this material are durable in a climate such as that of the Bighorn Basin. In a region where the rainfall is great the use of stucco blocks for buildings may not be advisable, but where the rainfall is only from 5 to 12 in. annually they are sufficiently durable to last a lifetime and within a moderate distance from the mill they are less expensive than lumber.

"Near the southeast end of Sheep Mountain, about 2 miles northeast of Greybull, a small amount of gypsum has been quarried and manufactured into stucco building blocks. It is hauled in wagons from the quarry a short distance to a small open kiln, where it is burned over a wood fire. After burning the gypsum is ground in a buhrstone mill driven by a gasoline engine. The kiln is 8 by 11 by 5 ft. and holds 12 to 15 wagonloads of material. About 500 blocks 8 by 9 by 24 in. are made from each burning. During 3 months in the spring and summer of 1915 2500 blocks were made at this locality by the method above described. The blocks sell at 10 cts. each at the kiln and 15 cts. each delivered at Greybull.

"Gypsum is not known to have been utilized elsewhere in the area described in this report, and it seems doubtful if the development of the gypsum industry in this general region will be rapid, owing to the large amount of good sandstone and limestone of building quality in the Bighorn Basin and adjacent parts of Wyoming.

"As this report goes to the printer word comes that a mill is being installed at Stucco which will handle the gypsum quarried at that locality. The situation is so convenient to the railroad that the product will probably be shipped to all parts of the Bighorn Basin."

Canada.[1]—The total quantity of gypsum rock quarried in 1916 was 422,741 short tons, of which 92,864 tons was calcined. The shipments of gypsum of all grades totalled 341,618 tons, valued at $730,831, and included lump, 249,759 tons, crushed 15,680 tons, fine-ground 6057 tons and calcined 70,122 tons.

In 1915 the quantity quarried was 505,989 tons, of which 84,763 tons was calcined. The shipments included: lump 346,947 tons, crushed 48,735 tons, fine-ground 6453 tons, and calcined 72,678 tons, or a total of 474,815 tons, valued at $854,929.

Exports of crude gypsum were 221,234 tons, valued at $252,476, while exports classed as gypsum or plaster, ground, rose to a value of $154,630. The corresponding exports in 1915 were crude gypsum 292,234 tons, valued at $336,380, and gypsum or plaster, ground, valued at $80,933.

R. U. Anderson, deputy inspector for Nova Scotia, in reporting on

[1] From Preliminary Report of the Mineral Production of Canada for 1916, Department of Mines.

the quarries in his territory, says that their total output for 1916 was 279,400 tons. Of the different quarries he says:[1]

"The Quarry at St. Anne's, Victoria county, owned and operated by the Victoria Gypsum, Mining & Manufacturing Co., Ltd., is about to be abandoned, a gypsum mine being opened. This is the only gypsum mine in Nova Scotia. It was begun in the summer of 1916. The mine, when I visited it, Aug. 24, consisted of an adit, driven into the base of a hill, 180 ft. and a slope, pitching 30°, driving to join the adit. The slope is about 8 ft. wide inside the timber and averages 8 ft. high. It is securely timbered down to the gypsum, which I examined carefully and tested in a number of places. The roof and sides, which are gypsum, I found solid and apparently safe.

"The adit is the same width as the slope, and is timbered as far as the rock, with round timber about 6 in. in diameter. A 'kettle-hole' occurred 85 ft. from the entrance of the adit; this hole will be timbered closely to keep the mud from running into the mine. The adit will drain all the workings.

"The gypsum is hauled in the slope in a half-ton sinking-car, the pitch of the slope giving height for a tipple to the shipping cars. About 2 per cent. of the product is lost in handling.

"The quarry and calcining mill at Iona, Victoria County, is owned by the Iona Gypsum Co., Ltd., and is about 2 miles north of Iona station on the Washabuckt road. The quarry produces 35 tons of crude gypsum a day and about 85 per cent. of this is calcined; between 15 and 20 per cent. is lost in milling. The property is estimated to contain 25,000,000 tons of gypsum. The quarrying is all done by hand and work continues the year round. The output for the year is 6012 tons.

"Ottawa-Brook quarry, owned by the Newark Lime & Cement Co., is about 2 miles west of Ottawa Brook station on the C. G. R. This quarry produced 925 tons during the year, but no shipments were made, due to the scarcity of vessels. The railway was extended about 1½ miles to a larger deposit of gypsum and the company intends to make larger shipments next year.

"Avondale quarry, Avondale, owned by the Newport Plaster, Mining & Manufacturing Co. is about 3 miles from Avondale, and is connected with the shipping wharf at Avondale by a railway. The quarry is being prepared for an aerial l-line which will extend about 500 ft. across a deposit of good gypsum. The production for the year is 42,739 tons. Seventy-five men and 17 horses were employed during the year. The product was shipped to J. B. King Co., New York.

"Wentworth Gypsum Co's. quarries, Wentworth, produced last year 185,464 tons. The Fraser quarry of this company is the largest gypsum quarry in Nova Scotia and is worked open face to a depth of 100 ft. The product is lifted to the cars by aerial cables, 500 ft. between the towers. The plant is in good condition. The product is shipped to New York.

"Patterson quarry, Kent Shore, is a comparatively new quarry, having been operated for 2 years. There are 10 men and 5 horses employed during the year. The quarry is about 1½ miles from tidewater on Minas Basin and a corduroyed road."

In Ontario, the Ontario Gypsum Co. was formed by a consolidation of the Crown Gypsum Co., with plant at Lythmore and the Alabastine Co., Ltd., of Paris. Its capitalization is $750,000. The mines and plant

[1] *Rock Products and Building Materials*, April 22, 1917.

of the Alabastine Co. are at Caledonia, while the head office and sales department are at Paris.

The output of Ontario for 1916 (crushed, ground and calcined) was 36,668 tons, valued at $116,206.

Australia.—Two small gypsum mills have recently been built at Marion Bay, York Peninsula, South Australia. The gypsum is obtained from extinct lakes in the beds of which the gypsum is formed as a single 18-in. layer. The presence of salt in connection with the gypsum is a serious handicap, and difficulties grow out of vegetable discoloration also.

There are miles of excellent gypsum in Western Australia about 350 miles from Freemantle, but transportation to the sea coast is too expensive to permit of their development.

IRON AND STEEL

The past year was by long odds the most prosperous the American steel trade has ever known. From start to finish, manufacturing establishments were driven to the very limit of their capacity, which can hardly be said of any previous year. The immediate participation in the great struggle of practically all other important iron-making nations, and the need for war purposes with most of them for more iron and steel than their own output, precipitated upon the United States a demand far beyond anything that an export enthusiast could possibly have pictured. It began in 1915 but grew much heavier in 1916. Thus was brought about a distortion of the trade relations of the whole world. Not only were belligerents unexpectedly large buyers, but neutral countries generally, that had been cut off from their usual sources of supply, became heavy purchasers of American steel. Only a portion of the details of such transactions reached the public at the time they were consummated, but enough became known to establish the fact that numerous steel purchases by belligerents were of staggering proportions; while the neutrals also showed a disposition to take greater quantities than it had been supposed their needs would require.

Although conditions at the close of 1915, when the demand was insatiable, looked as if they would never again be equaled, they were far surpassed by the achievements of 1916. The contracts for far-distant delivery placed at high prices in the last 2 months of the year plainly showed a disposition to speculate on the indefinite continuance of the war. Although prices have long been regarded as dangerously high, the belief of some in the steel trade is that when readjustments come they will be gradual and not so violent as to cause disaster. On the other hand are those who emphasize the possibility of radical changes in prices after the war and also of the competition of foreign-made steel products in this market.[1]

One of the striking features of the year was the consolidation with the Bethlehem Steel Co. of the Pennsylvania Steel Co., the Maryland Steel Co., the Titusville Forge Co. and the American Iron and Steel Manufacturing Co., and the consolidation of the Midvale Steel Co. and the Cambria Steel Co., two of the biggest mergers in the steel industry since the formation of the U. S. Steel Corporation.

[1] *Iron Age*, Jan. 4, 1917.

IRON ORE

The shipments of iron ore from the mines in the United States in 1916 are estimated by the United States Geological Survey to have approximated 75,500,000 gross tons, compared with 55,493,100 tons in 1915, an increase of 34 per cent. This ore sold for approximately $178,935,000, an increase of about $77,650,000 compared with the value of the 1915 output. Ore in stock at the mines is estimated at approximately 10,486,000 gross tons, compared with 13,748,732 tons in 1915, a decrease of nearly 24 per cent.

Of the total shipments of iron ore 64,734,198 gross tons was shipped by boat from the Lake Superior district, according to detailed figures from the docks of upper Lake ports published recently by the *Iron Age*, and possibly 1,300,000 tons in addition was shipped by rail, making the probable total shipments from the mines in the Lake Superior district more than 66,000,000 gross tons. Compared with the boat and rail shipments from this district in 1915 (47,272,751 gross tons), an increase of nearly 40 per cent. is shown.

IRON ORE MINED IN THE UNITED STATES IN 1914 AND 1915, GROSS TONS

State.	1914.	1915.
Minnesota	21,946,901	33,464,660
Michigan	10,796,200	12,514,516
Alabama	4,838,959	5,309,354
Wisconsin	886,512	1,095,388
New York	785,377	998,845
Wyoming	366,962	434,513
New Jersey	350,135	415,234
Pennsylvania	406,326	363,309
Virginia	378,520	348,042
Tennessee	330,214	284,185
Georgia	67,722	115,701
North Carolina	57,667	66,453
Missouri	37,554	40,290
New Mexico	81,980	34,806
Colorado	10,464	*
Connecticut	9,149	*
Maryland	6,369	5,500
Nevada	*	3,993
Massachusetts	7,600	3,950
Ohio	5,138	3,455
California	1,282	646
Kentucky	21,400	....
West Virginia	6,530	....
Other States†	40,800	23,650
	41,439,761	55,526,490

* Less than three producers in Colorado and Connecticut in 1915 and in Nevada in 1914, and permission was not granted to publish State totals.

† 1914: Idaho, Mississippi, Montana, Nevada, and Utah; 1915: Colorado, Connecticut, Idaho and Utah.

The shipments of iron ore from all the other important iron-mining districts in the United States showed increases ranging from 3.2 to 49 per cent. The Birmingham and other Alabama districts are estimated to have shipped to blast furnaces approximately 5,300,000 gross tons, compared with 5,134,955 tons in 1915, an increase of 3.2 per cent. The other Southeastern States, including Georgia, North Carolina, Tennessee, and Virginia, are estimated to have shipped approximately 1,000,000 gross tons, compared with 786,437 tons in 1915, an increase of 27 per cent. The Northeastern States, including New York, New Jersey, and Pennsylvania, are estimated to have shipped approximately 2,500,000 gross tons, compared with 1,689,916 tons in 1915, an increase of nearly 48 per cent. The Western States, including Colorado, New Mexico, and Wyoming, are estimated to have shipped approximately 725,000 gross tons, compared with 485,942 tons in 1915, an increase of 49 per cent.

Production by districts is as follows:

IRON ORE MINED IN THE UNITED STATES, BY MINING DISTRICTS

District.	1914.	1915.	1916
Lake Superior*	33,540,403	46,944,254	....
Birmingham	4,282,556	4,748,929	....
Chattanooga	432,006	539,024	....
Adirondack	544,724	699,213	....
New Jersey and S. E. New York	541,084	644,493	....
Other districts	2,098,988	1,950,577	....
	41,439,761	55,526,490	75,500,000

* Includes only those mines in Wisconsin which are in the true Lake Superior district.

Lake Superior District.[1]—The 1916 shipments showed a gain of 19,385,715 tons over 1915, when 47,272,751 tons was forwarded. This increase was 41.01 per cent. of the total movement during 1915, which year in turn had shown a gain of 44.43 per cent. of the 1914 movement.

The lake movement in 1916 was 64,734,198 tons, compared with 46,318,804 tons in 1915, a gain of 18,415,394 tons. The all-rail shipments of 1,924,268 tons compared with a rail movement of 953,947 tons in 1915, a gain of 970,321 tons, or more than 100 per cent. The all-rail movement was by far the largest of any year in the history of the district.

PRODUCTION OF IRON ORE IN LAKE SUPERIOR DISTRICT
(In tons of 2240 lb.)

Year.	Tonnage.	Year.	Tonnage.	Year.	Tonnage.	Year.	Tonnage.	Year.	Tonnage.
1855...	1,449	1880..	1,948,334	1902..	27,562,566	1907..	42,266,668	1912..	46,483,798
1860...	114,401	1885..	2,466,642	1903..	24,289,674	1908..	26,014,987	1913..	52,518,158
1865...	193,758	1890..	9,003,725	1904..	21,822,839	1909..	42,586,869	1914..	33,629,613
1870...	859,507	1895..	10,429,037	1905..	34,353,456	1910..	43,442,397	1915..	46,994,254
1875...	881,166	1900..	19,059,393	1906..	38,522,239	1911..	32,793,120	....	....

SHIPMENTS OF IRON ORE FROM LAKE SUPERIOR DISTRICTS
(In tons of 2240 lb.)

Range.	1911.	1912.	1913.	1914.	1915.	1916.
Marquette	2,833,116	4,202,308	3,966,680	2,491,857	4,105,378	5,396,007
Menominee	2,911,174	4,711,440	4,965,604	3,221,258	4,982,626	6,364,363
Gogebic	2,603,318	4,996,498	4,531,558	3,568,482	5,477,767	8,489,685
Vermillion	1,088,930	1,844,981	1,566,600	1,016,993	1,733,595	1,947,200
Mesabi	22,093,532	32,047,409	34,038,643	21,465,967	29,756,689	42,525,612
Baraboo	115,629	104,031	145,010	105,765	80,583	1,716,218
Cuyuna	147,431	305,111	733,021	859,404	1,136,113	219,381
Total	31,793,130	48,211,778	49,947,116	32,729,726	47,272,751	66,658,466

[1] *Iron Tr. Rev.*, Mar. 1, 1917.

Shipments from the Lake Superior district by independent companies again exceeded those of the United States Steel Corporation. In 1916, the independents forwarded 52.48 per cent. of the total tonnage, compared with 52.37 per cent. in 1915. The 1915 record had been the highest since the formation of the Steel Corporation. Last year was the fifth successive year in which the independent companies have moved more than one-half of the ore shipped from the Lake Superior district. In 1914, the independents shipped 50.99 per cent. of the total, compared with 50.94 in 1913 and 50.54 in 1912. In one other year since 1905 have the independents shipped the majority of the tonnage, that being 1910, when their percentage was 50.14. The percentage in 1906 was 47; 1907 and 1908, 44; 1909, 49.64; and 1911, 47.30. The strength of the independent ore interests is clearly revealed by their record of having forwarded more than one-half of the season's tonnage in 6 of the last 7 years.

The following table shows the shipments and percentage of the Oliver Iron Mining Co., the Steel Corporation's mining organization, for each of the last 9 years:

Year.	Gross Tons.	Percentage.
1908	14,123,957	56.00
1909	21,397,866	50.36
1910	21,661,143	49.86
1911	17,282,499	52.70
1912	23,845,363	49.46
1913	24,502,244	49.06
1914	16,039,654	49.01
1915	22,518,613	47.63
1916	31,673,131	47.52

Shipments from the Mesabi range in 1916 were 42,525,612 tons, against 29,756,689 tons in 1915, a gain of 12,768,923 tons. Its percentage of the total shipments was 63.80, against 62.95 in 1915. The Gogebic range again ranked as the second largest shipper, forwarding 8,489,685 tons, against 5,477,767 tons in 1915, a gain of 3,011,918 tons. Its percentage in 1916 was 12.74, against 11.59 in 1915. The Menominee range also showed a large increase in the tonnage forwarded, its shipments for 1916 being 6,364,363 tons, compared with 4,982,626 tons in 1915, a gain of 1,381,737 tons. Its percentage was 9.55, against 10.54 in 1915. The Marquette range did not show as great a gain in 1916 as in the previous year, 1916 shipments being 5,396,007 tons, against 4,105,378 tons in 1915, a gain of 1,290,629 tons. Its percentage was 8.09 in 1916, against 8.68 in 1915. Vermillion range shipments were 1,947,200 tons against 1,733,595 tons in 1915, a gain of 213,605 tons. Its percentage was 2.92, against 3.67 in 1915.

All ranges, with the exception of the Vermillion, set new records last year in the tonnage of ore shipped. The record of 8,489,685 tons made by the Gogebic greatly exceeded its previous record set in 1915 with 5,477,767 tons. The greatest tonnage ever forwarded from the Menominee, prior to last year, was in 1906, when 5,109,088 tons was shipped. In 1916, the Menominee shipped 6,364,363 tons. The Marquette shipments for 1916 greatly exceeded the record year of 1910, last year's total being 5,396,007 tons compared with 4,392,726 tons in 1910. The Vermillion's 1916 total was the highest with the exception of 1902, when 2,084,263 tons was forwarded.

Shipments from the Cuyuna range continue to increase. The total tonnage forwarded from the newest range last year was 1,716,218 tons, compared with 1,136,113 tons in 1915, a gain of 580,105 tons. The Cuyuna's percentage of the total shipments for 1916 was 2.57, a slight increase over the 1915 percentage of 2.40.

Proportional shipments by ranges are as follows:

	1911.	1912.	1913.	1914.	1915.	1916.
Mesabi	67.37	66.46	68.15	65.62	62.95	63.80
Gogebic	7.94	10.38	9.07	10.90	11.59	12.74
Menominee	11.93	9.77	9.94	9.83	10.54	9.55
Marquette	8.64	8.71	7.94	7.61	8.68	8.09
Vermillion	3.32	3.83	3.14	3.10	3.67	2.92
Cuyuna	0.45	0.63	1.47	2.62	2.40	2.57

The ore was forwarded as indicated below:

SHIPMENTS BY PORTS AND ALL-RAIL
(Gross tons)

	1911.	1912.	1913.	1914.	1915.	1916.
Escanaba	4,278,445	5,234,655	5,399,444	3,664,451	5,649,289	7,457,444
Marquette	2,200,380	3,296,761	3,137,617	1,755,726	3,099,589	3,858,092
Ashland	2,429,290	4,797,101	4,338,230	3,363,419	5,146,772	8,057,814
Two Harbors	6,367,537	9,370,969	10,075,718	5,610,262	8,642,942	10,735,853
Superior	9,920,490	14,240,714	13,788,343	11,309,748	8,342,793	12,787,046
Duluth	6,934,269	10,495,577	12,331,126	6,318,291	15,437,419	21,837,949
Total by lake	32,130,411	47,435,777	49,070,478	32,021,897	46,318,804	64,734,198
Total by rail	662,719	785,769	876,638	707,829	953,947	1,924,268
Total	32,793,130	48,221,546	49,947,116	32,729,726	47,272,751	66,658,466

The following table shows the average shipments of all the mines on the six leading ranges and of the whole Lake Superior district for 1914, 1915 and 1916.

AVERAGE MINE SHIPMENTS

	1914.	1915.	1916.
Mesabi	228,361	306,769	397,436
Vermillion	169,499	247,656	243,400
Gogebic	169,928	210,683	339,585
Marquette	99,674	146,621	119,852
Menominee	78,567	124,566	141,430
Cuyuna	122,772	113,611	95,345
Lake Superior district	166,988	226,186	286,087

Twelve mines shipped more than 1,000,000 tons last year, these mines being the Burt, Canisteo, Fayal, Hull-Rust, Leonidas, Mahoning, Morris and Sellers on the Mesabi; Newport, Norrie Group and Wakefield on the Gogebic, and Cleveland-Cliffs Group on the Marquette. In 1915 there were seven mines which reached this figure, they being the Burt, Canisteo, Hull-Rust, Mahoning, Morris and Sauntry-Alpena on the Mesabi and the Norrie Group on the Gogebic. In 1914 only four mines shipped more than 1,000,000 tons, they being the Leonard, Mahoning, Sauntry-Alpena and Canisteo, all on the Mesabi. In 1913, eleven mines reached the 7-figure mark in shipments, they being the Adams, Canisteo, Fayal, Genoa, Hull-Rust, Leonard, Mahoning, Sauntry-Alpena and Uno South on the Mesabi and the Norrie Group and Newport on the Gogebic. Eleven mines also reached that figure in 1912, they being the Canisteo, Dale, Genoa, Hill, Hull-Rust, Leonard, Mahoning, Sauntry-Alpena and Uno South on the Mesabi, the Norrie Group on the Gogebic and the Cleveland-Cliffs Group on the Marquette. The mines which shipped more than 1,000,000 tons in 1911 were Canisteo, Dale, Hill, Leonard, Mahoning and Sauntry-Alpena, all on the Mesabi.

The wonderful Hull-Rust mine was the leading shipper last year, forwarding the immense total of 7,665,611 tons, or more than the shipments from any of the ranges, excepting the Mesabi and Gogebic. The previous record made by this mine was in 1913 with shipments of 3,457,608 tons. Two other mines shipped over 2,000,000 tons, the Fayal, with 2,288,799 tons and the Mahoning with 2,215,788 tons. The Mahoning was the leading shipper in 1915, with 2,311,940 tons. The Hull-Rust has been the leading shipper in 7 of the last 10 years, the Hill leading in 1911.

The following new mines shipped in 1916:

On the Mesabi: Jean, of the Kingston Mining Co.; Kerr and Ordean, of the Oliver Iron Mining Co.; Kevin, of Butler Bros.; Langdon & Warren 40, of the Arthur Iron Mining Co.; St. James, of Corrigan, McKinney & Co.; and Tioga, of the Shenango Furnace Co.

On the Menominee: Amasa-Porter, of the Judson Mining Co.; Odgers, of Corrigan, McKinney & Co.; Warner, of Pickands, Mather & Co.

On the Cuyuna: Croft, of the Merrimac Mining Co.; Cuyuna-Sultana, of the Cuyuna-Sultana Iron Co.; Ferro, of the Onahman Mining Co.; Hill Crest, of the Hill Mines Co.; Mahnomen, of the Mahnomen Mining Co.; Mangan, of the Mangan Iron & Steel Co.; Meacham, of the Rogers, Brown Ore Co.; State Lease, of the Inland Steel Co.

On the Gogebic: Plymouth, of Coates & Tweed.

On the Marquette: Isabella, of the Cascade Mining Co.

On the Vermillion: Consolidated Vermillion, of the Consolidated Vermillion & Extension Co.

On the Mayville-Baraboo: Cahoon, of the Donner Steel Co.

The total of 22 new shippers in 1916 is the same as the total in 1915. In 1914, 16 new mines were opened; 20 in 1913; 13 in 1912; and 12 in 1911. Seven of the new mines shipping last year are located on the Mesabi, three on the Menominee, eight on the Cuyuna and one each on the Gogebic, Marquette Vermillion and Mayville-Baraboo. Shipments from the new mines totaled 2,357,850 tons in 1916, compared with 1,203,213 tons in 1915; 677,182 tons in 1914; 831,567 tons in 1913; 361,904 tons in 1912 and 1,769,423 tons in 1911.

Several mines which had been idle for years shipped ore in 1916. The Monongahela mine on the Menominee range, which had not made a shipment since 1903, again returned to the active list. The Higgins and Victoria mines, which had not forwarded ore since 1911 again shipped in 1916, and the Illinois, on the Mayville-Baraboo range, idle since 1908, also was among the shippers last year.

Leading shippers of the different ranges are as follows:

	1914.	1915.	1916.
Mesabi:			
Burt	213,433	1,043,607	1,060,487
Canisteo	1,051,895	1,622,182	1,943,745
Fayal	....	774,096	2,288,799
Hull-Rust	458,468	2,294,405	7,665,611
Leonard	2,687,285	197,599	316,468
Leonidas	....	732,777	1,147,105
Mahoning	1,212,287	2,311,940	2,215,788
Morris	365	1,167,421	1,609,971
Sauntry-Alpena	1,131,255	1,455,825	933,937
Sellers	....	721,908	1,344,121
Menominee:			
Bristol	....	378,786	462,559
Caspian	279,379	479,084	448,631
Chapin	340,722	384,654	557,485
Marquette:			
Cleveland-Cliffs	673,160	634,837	1,036,775
Negaunee	....	480,521	523,736
Gogebic:			
Montreal	....	464,272	530,813
Newport	....	838,875	1,315,980
Norrie Group	984,242	1,408,516	1,855,863
Wakefield	....	651,302	1,061,730
Vermillion:			
Pioneer	....	453,099	507,086
Zenith	424,110	714,852	482,783
Cuyuna:			
Armour No. 2	283,565	303,280	341,147
Pennington	....	117,068	206,085
Mayville-Baraboo:			
Mayville	103,549	80,583	125,970

In 1916, 233 mines shipped, compared with 209 mines in 1915; 196 in 1914; 223 in 1913; 194 in 1912, and 184 in 1911. Of those shipping last year, the Mesabi had 107, Menominee 45, Marquette 27, Gogebic 25, Cuyuna 18, Vermillion 8 and Mayville-Baraboo 3. In 1915, the Mesabi shippers numbered 97, Menominee 40, Marquette 28, Gogebic 26, Cuyuna 10, Vermillion 7, and Mayville-Baraboo 1.

Michigan.[1]—The Michigan iron ranges took their part in the extraordinary iron production of 1916 and were free from the I. W. W. disturbances that took place on the Mesabi Range in Minnesota. Wages were raised three times during the year, with an aggregate increase of about 30 per cent., but labor was difficult to get up to the close of navigation. On the Gogebic Range, the Jones & Laughlin Ore Co. opened a new deposit at Wakefield near the Hanousek property. From the Hanousek openpit about 300,000 tons was shipped in 1916 by Coates & Tweed, of Duluth, Minn.; this promises to be the second largest openpit mine in Michigan. At Ironwood the Newport Mining Co. broke the shaft-sinking records of the Gogebic Range in sinking the new Woodbury shaft.

The Cleveland-Cliffs Iron Co. at Ishpeming practically completed its preparations for placing the Holmes mine in the shipping list; the mine has the highest headframe of any Michigan iron mine. At Negaunee the company is sinking the Athens shaft to 2600 ft., having attained a depth of 2200 ft. in December. At Bessemer, a new shaft was begun for the Colby mine. The Cleveland-Cliffs company also opened new ore by drilling in the Lake Angeline mine near Ishpeming and is stripping; this was an underground mine and supposed to have been worked out. On the Marquette Range the same company opened the Section 6 pit at North Lake. Corrigan, McKinney & Co. brought into production on the Menominee Range the Odgers mine at Crystal Falls.

FOREIGN ORE IMPORTS DURING LAST FIVE YEARS

	1912.	1913.	1914.	1915.	1916.
Cuba	1,398,593	1,635,622	815,017	831,618	716,571
Sweden	333,863	356,074	280,887	204,632	212,063
Spain	92,061	112,580	66,982	42,092	161,422
Chile	....	....	45,000	146,000	....
Canada	100,675	179,860	52,514	84,124	136,835
Africa	....	12,950	46,175	22,000	....
Miscellaneous	173,584	297,684	44,793	10,815	98,845
	2,104,576	2,594,770	1,351,368	1,341,281	1,325,736

Of the tonnage imported in 1915, the port of Philadelphia received 687,780 tons; Baltimore, 572,813 tons; and the balance came in at Cleveland, Chicago and other ports.

Exports.—Exports of iron ore from the United States in 1916 amounted to 1,183,952 tons, as compared with 707,641 tons in 1915.

Iron and Steel Markets

Pittsburgh.[2]—The year 1916 in the iron and steel trade was one of unparalleled activity in the market, of unprecedentedly rapid price

[1] *Eng. Min. Jour.*, Jan. 6, 1917.
[2] B. E. V. Luty, *Eng. Min. Jour.*, Jan. 6, 1917.

advances and of record output. The remarkable character of the year's market is most clearly shown by the prices attained. During 1915 finished-steel prices had passed the maximum reached in 1912 and 1909 and were equal to the prices reached in 1907. In 1916 there were successively passed the maximum levels reached in 1902 and in 1899, and thus steel prices reached a new high level in the history of the industry, for it was during the depression of 1893–1898 that steel supplanted wrought iron as the dominant finished product. Comparing the merchant steel bars of the present with the merchant iron bars of the past, equally high prices were found only from September, 1879, to April, 1880, and from the latter part of the Civil War until March, 1874.

As to pig iron the comparison is somewhat different, pig iron having advanced much less rapidly than steel in 1915. At the beginning of 1916 pig iron was slightly higher than it was at the top point in the 1912 movement and equal to the top reached in the 1909 movement, but it was much cheaper than in 1907. By the close of 1916 it had passed successively the high levels of 1907 and 1899 and was at the highest price since April, 1880.

In the early years of pig-iron manufacture in the United States, prices were necessarily very high as compared with recent standards, because the process of manufacture was crude and expensive; but there is record of some relatively low prices long ago, for in 1803 the average price of charcoal pig iron delivered Philadelphia, no doubt involving a considerable freight charge, as there were no railroads, was $29.25. At the close of 1916 the average price of coke pig iron at furnace in the various important producing districts was approximately $30.

During the first 8 months of 1916 the pig-iron markets were practically stationary, following the moderately sharp advance that occurred during the second half of the preceding year. In September, October and November prices rose very sharply, by an average of more than $12 a ton, there being very little movement in December.

The course of steel prices was different. There was a rapid advance during the first 3 months of 1916, following the rising movement of the preceding year, and then from April to July inclusive the advances were relatively small. In August there began what had all the appearance of a fresh movement, carrying prices sharply upward at as rapid a pace as was shown in the first 3 months of the year.

The demand of steel was heavy and insistent, and buyers rather than sellers caused the advances. The higher prices quoted by sellers early in the year were made in the expectation that buying for far-forward delivery would be checked, the mills being willing to have their order books cleared so that eventually they could participate in the higher

AVERAGE PRICES AT PITTSBURGH, 1916

	Pig Iron.			Steel.						Pipe, Basing Discount, Per Cent.	Wire Nails, Base, Cents.
	Bessemer.	Basic.	No. 2 Foundry.	Ferro-manganese.	Bessemer Billets.	Beams, Cents.	Plates, Cents.	Bars, Cts.	Black Sheets No. 28, Cents.		
January	$21.60	$18.78	$19.45	$118.00	$32.50	1.87	1.90	1.87	2.60	76¾	2.13
February	21.16	18.93	19.45	141.60	34.00	2.06	2.16	2.06	2.60	75½	2.26
March	21.81	19.20	19.45	177.60	41.00	2.36	2.53	2.36	2.73	73⅜	2.40
April	21.65	18.95	19.45	177.60	45.00	2.50	2.75	2.50	2.89	71½	2.40
May	21.78	19.11	19.39	177.60	43.00	2.50	2.83	2.50	2.90	70	2.50
June	21.95	18.95	19.34	177.60	42.00	2.50	2.90	2.50	2.90	70	2.50
July	21.95	18.95	19.20	177.60	42.50	2.50	2.90	2.50	2.90	70	2.50
August	21.95	18.95	19.22	177.60	46.00	2.54	2.94	2.56	2.90	70	2.58
September	22.88	19.58	19.53	167.60	47.00	2.60	3.00	2.60	2.91	69¼	2.60
October	24.60	21.25	21.51	167.60	48.00	2.63	3.07	2.62	3.23	69	2.64
November	30.07	28.17	26.55	167.60	52.75	2.86	3.33	2.76	3.72	68½	2.84
December	35.95	30.95	30.95	166.60	55.00	3.00	3.50	2.90	4.50	66	3.00
Year	23.95	20.98	14.64	166.17	44.06	2.50	2.82	2.48	2.52	70¾	2.53
Year 1915	15.81	14.80	14.77	93.59	22.45	1.30	1.20	1.31	1.92	79¼	1.66

Prices of pig iron, ferro-manganese and billets are per ton 2240 lb.; of steel products, per lb.; of nails, per 100 lb., base; of pipe, in discount on base sizes, ¾ to 3 in., from a list per foot equivalent to 10 cts. per lb.

prices secured for early deliveries by the small mills that were not filled up, but the volume of business constantly grew. The Steel Corporation's unfilled obligations rose from 8,000,000 to 11,000,000 tons during the year; in September, 1914, they had had less than 3,000,000 tons.

Chicago.[1]—Prices of pig iron advanced slightly through the first quarter of the year, remained stationary in the second quarter and sagged perceptibly in the third. Recovery of strength in the pig-iron market began in October and became most rapid in November. The maximum range of prices of Northern iron in the period of the year was approximately $12 per ton, from a minimum of $18 to a maximum of $30.

Two interesting facts are to be noted from the prices given for structural shapes and steel bars. The prices shown are those generally prevailing for prompt shipment, as contrasted with contract quotations for deliveries only at mill convenience. Sales of steel in the West at prompt shipment prices were a very much smaller proportion of the whole tonnage than was true in districts depending upon Pittsburgh and Eastern producers. The reason for this goes back to the fact that Western mills were much slower in acquiring a backlog in 1915 and the early part of 1916 than were the more easterly mills, and accordingly shipments against their contract obligations went forward to customers in a manner to meet the latter's needs without the necessity of buying prompt shipment material to much greater extent than was true elsewhere. Almost throughout the year users of structural shapes and bars in the West were working on material for current orders at a decidedly lower price

[1] *Iron Age*, Jan. 4, 1917.

level than were Eastern contemporaries. The higher premium level of prices was therefore less indicative of conditions in the West than in the East.

Another interesting fact made apparent in a comparison of the prices of structural material and soft steel bars is that in the early part of the year bars were selling at higher prices than shapes. In the third quarter, prices of both shapes and bars for prompt shipment became almost the same as contract quotations, while in the last quarter of the year structural steel began to sell again at the normal spread in advance of bars. Partial explanation of these changing relationships lay in the curtailment of structural-steel projects as the result of high prices.

The interesting feature about the prices of old materials as compared with the prices prevailing for new materials was the disproportionately low level of values which obtained through 10 months of the year. Not until the acute car and labor shortages made themselves most keenly felt at the approach of winter did the scrap market begin to gain strength, following which the advance in prices has had few parallels for rapidity.

AVERAGE CHICAGO PRICES OF PIG IRON AND STEEL

	Northern Coke No. 2.	Lake Superior Charcoal.	Southern Coke No. 2.	Common Bar Iron, Cents.	Soft Steel Bars, Cents.	Structural Steel, Cents.
January	$18.50	$19.50	$18.88	1.79	2.44	2.38
February	18.50	19.75	19.00	1.90	2.52	2.44
March	18.70	19.75	19.00	2.16	2.89	2.59
April	19.00	19.75	19.00	2.35	3.07	2.74
May	19.00	19.75	19.00	2.35	3.19	2.79
June	19.00	19.75	18.70	2.35	2.99	2.79
July	19.00	19.75	18.25	2.35	2.94	2.79
August	18.40	19.75	17.80	2.35	2.94	2.89
September	18.13	19.75	18.13	2.35	2.94	2.94
October	19.63	20.25	19.25	2.35	2.94	2.94
November	25.80	26.46	23.70	2.55	3.02	3.19
December	29.50	31.75	27.50	2.88	3.34	3.44
Average for year	20.25	21.33	19.85	2.31	2.94	2.83
Average for 1915	14.02	16.10	14.73	1.24	1.484	1.482
Average for 1914	13.60	15.60	14.46	1.06	1.32	1.34
Average for 1913	15.95	16.50	16.12	1.43	1.55	1.60
Average for 1912	15.32	16.77	16.11	1.32	1.42	1.46
Average for 1911	14.87	16.96	14.80	1.22	1.47	1.50
Average for 1910	17.10	18.67	16.30	1.45	1.62	1.66
Average for 1909	17.49	19.50	17.30	1.43	1.50	1.59
Average for 1908	17.57	20.24	16.76	1.56	1.66	1.82

Pig Iron

At the beginning of the year, daily production was at the rate of 102,746 tons. This gradually increased to 108,422 tons in May, and then declined to 103,346 tons in August, recovered rapidly, reaching a maximum of 113,189 tons in October, and then declined to 102,293 tons at the end of the year. Since operations for the entire year were crowded

MONTHLY PRODUCTION

	1916.	1915.	1914.	1913.
January	3,185,121	1,591,024	1,879,336	2,787,800
February	3,087,212	1,666,592	1,888,607	2,578,670
March	3,337,691	2,046,280	2,341,551	2,762,823
April	3,227,768	2,114,518	2,261,501	2,754,353
May	3,361,073	2,255,157	2,097,019	2,816,825
June	3,211,588	2,369,932	1,904,566	2,616,883
Total first half	19,410,453	12,043,503	12,372,580	16,317,354
July	3,224,513	2,563,311	1,955,324	2,558,275
August	3,203,713	2,774,825	1,996,483	2,537,018
September	3,202,366	2,834,342	1,882,718	2,494,098
October	3,508,849	3,120,340	1,767,227	2,539,924
November	3,311,811	3,035,235	1,501,269	2,229,960
December	3,171,087	3,201,605	1,495,325	1,976,138
Total second half	19,622,339	17,529,658	10,598,346	14,335,413
Grand total	39,032,792	29,573,161	22,970,926	30,652,767

to practically the maximum possible capacity, there was an unusual absence of variation from month to month, as shown in the accompanying table of monthly production.

Pig-iron output in the United States since 1820 is given in the following table:

PIG-IRON PRODUCTION FOR 100 YEARS

1820	20,000	1861	653,164	1882	4,623,323	1903	18,009,252
1828	130,000	1862	703,270	1883	4,595,510	1904	16,497,033
1829	142,000	1863	846,075	1884	4,097,868	1905	22,992,380
1830	165,000	1864	1,014,282	1885	4,044,526	1906	25,307,191
1831	191,000	1865	831,770	1886	5,683,329	1907	25,781,361
1832	200,000	1866	1,205,663	1887	6,417,148	1908	15,936,018
1840	286,903	1867	1,305,023	1888	6,489,738	1909	25,795,471
1842	215,000	1868	1,431,250	1889	7,603,642	1910	27,303,567
1846	765,000	1869	1,711,287	1890	9,202,703	1911	23,649,547
1847	800,000	1870	1,665,179	1891	8,279,870	1912	29,726,937
1848	800,000	1871	1,706,793	1892	9,157,000	1913	30,966,301
1849	650,000	1872	2,548,713	1893	7,124,502	1914	23,332,244
1850	563,755	1873	2,560,963	1894	6,657,388	1915	29,916,213
1852	500,000	1874	2,401,262	1895	9,446,308	1916	39,434,797
1854	657,337	1875	2,023,733	1896	8,623,127		
1855	760,159	1876	1,868,961	1897	9,652,680		
1856	788,515	1877	2,066,594	1898	11,773,934		
1857	712,640	1878	2,301,215	1899	13,620,703		
1858	629,548	1879	2,741,853	1900	13,789,242		
1859	750,650	1880	3,835,191	1901	15,878,354		
1860	821,223	1881	4,144,254	1902	17,821,307		

Below is given the production by half-yearly periods for 1911 to 1916, in gross tons as compiled by the American Iron and Steel Institute. All pig iron and ferro-alloys are included, whether made in blast furnaces or in electric furnaces.

Periods.	1911.	1912.	1913.	1914.	1915.	1916.
First half	11,666,996	14,072,274	16,488,602	12,536,094	12,233,791	19,619,522
Second half	11,982,551	15,654,663	14,476,699	10,796.150	17,682,422	19,815,275
Total	23,649,547	29,726,937	30,966,301	23,332,244	29,916,213	39,434,797

The total increase in production, amounting to 32 per cent., is quite uniformly distributed among the important producing States, as is shown in the following table of production by States. Only the New England States showed a decrease.

PRODUCTION OF PIG IRON BY STATES
(In tons of 2240 lb.)

States.	1910.	1911.	1912.	1913.	1914.	1915.	1916.
Massachusetts and Connecticut	16,582	9,649	17,366	12,810	6,594	7,802	5,719
New York	1,938,407	1,562,756	1,939,231	2,187,620 (New York and New Jersey)	1,559,864	2,104,780	2,352,535
New Jersey	264,781	40,663	36,876				
Pennsylvania	11,272,323	9,807,073	12,552,131	12,954,940	9,733,369	12,790,668	16,506,824
Maryland	326,214	255,816	219,546	289,959	195,594	251,548	501,452
Virginia	444,976	293,642	256,167	341,815	271,228	251,346	399,885
Alabama	1,939,147	1,712,211	1,862,681	2,057,911	1,826,929	2,049,453	2,762,885
N. Car., Geo., Texas	14,725	1,200	*Nil.*	....	....	....	....
West Virginia	174,661	291,472	274,360	315,731 (West Virginia and Kentucky)	(*b*)236,393	(*b*)291,040	(*b*)554,590
Kentucky	100,509	95,202	68,760				
Tennessee	397,569	324,648	338,238	280,541	216,738	177,729	355,374
Ohio	5,752,112	5,310,506	6,802,493	7,129,525	5,283,426	6,912,962	8,602,895
Illinois	2,675,646	2,108,002	2,887,359	(*a*)2,927,977	1,847,451	2,447,220	3,922,512
Michigan	(*a*)1,250,103	1,163,932	(*a*)1,770,628	1,775,883	(*a*)1,557,355	*a*1,986,778	(*a*)2,221,708
Wisconsin, Minn.	307,200	276,807	303,370	367,326	329,526	372,966	811,325
W. of Miss. River	428,612	395,968	397,731	324,263	267,777	271,921	437,633
Total	27,303,567	23,649,547	29,726,937	30,966,301	23,332,244	29,916,213	39,434,797

(*a*) Includes Indiana. (*b*) Includes Mississippi.

Production of pig iron from 1910 to 1916 according to fuel used, is given below:

PIG-IRON PRODUCTION ACCORDING TO THE FUEL USED
(In tons of 2240 lb.)

Fuel Used.	1910.	1911.	1912.	1913.	1914.	1915.	1916.
Coke(*a*)	26,257,978	23,141,296	29,132,733	30,348,973	22,976,856	29,535,308	38,844,598
Anthracite & coke	628,579	212,548	236,467	254,901	91,464 (Anthracite & coke and Anthracite alone)	84,753	217,788
Anthracite alone	20,503	17,027	10,712	22,446			
Charcoal / Charcoal & coke	396,507	278,676	347,025	339,981	263,924	296,152	372,411
Total	27,303,567	23,649,547	29,726,937	30,966,301	23,332,244	29,916,213	39,434,797

(*a*) Under coke furnaces are included the very few which use raw bituminous coal. It may be assumed that 99 per cent. of this class of iron was made with coke.

Below is listed the production of pig iron according to character of product. Low-phosphorus pig iron, that is, running under 0.04 per cent. phosphorus, is included in Bessemer pig iron; the latter is iron containing from 0.04 to 0.10 per cent. phosphorus. The figures for the last 3 years include under basic iron a small quantity of charcoal iron of basic grade. Nearly all of the charcoal iron is classed as foundry iron; pig iron of high silicon-content is included in the foundry group, while under "all other grades" are included white and mottled iron, direct castings, and miscellaneous ferro-alloys.

PRODUCTION OF PIG IRON BY GRADES, 1907–1916

Years.	Basic.	Bessemer.	Foundry.	Malleable.	Forge.	All Other.	Total, Gross Tons.
1907	5,375,219	13,231,620	5,151,209	920,290	683,167	419,856	25,781,361
1908	4,010,144	7,216,976	3,637,622	414,957	457,164	199,155	15,936,018
1909	8,250,225	10,557,370	5,322,415	658,048	725,624	281,789	25,795,471
1910	9,084,608	11,245,642	5,260,447	843,123	564,157	305,590	27,303,567
1911	8,520,020	9,409,303	4,468,940	612,533	408,841	229,910	23,649,547
1912	11,417,886	11,664,015	5,073,873	825,643	469,183	276,337	29,726,937
1913	12,536,693	11,590,113	5,220,343	993,736	324,407	300,860	30,966,152
1914	9,670,687	7,859,127	4,533,254	671,771	361,651	235,754	23,332,244
1915	13,093,214	10,523,306	4,864,348	829,921	316,214	289,210	29,916,213
1916	17,684,087	14,422,457	5,553,644	921,486	348,344	504,779	39,434,797

This table shows the heaviest increases in the basic and Bessemer grades (that is, the irons from which steel is made) rather than the foundry grades.

Of the 39,434,797 tons of pig iron made in 1916, 11,253,317 tons, or 28.5 per cent. was for sale, and 28,181,480 tons was for the maker's use; in 1915 the proportion for sale was 28.7 per cent.

The number of blast furnaces in the United States at the close of each year since 1911, is given in the following table:

BLAST FURNACES IN UNITED STATES

Fuel Used—Blast Furnaces.	1911.	1912.	1913.	1914.	1915.	1916.
Bituminous coal and coke	385	395	394	389	390	388
Anthracite, and anth. and coke	35	26	23	20	15	20
Charcoal	45	45	45	42	40	40
Total	465	466	462	451	445	448

New blast furnaces projected in 1916 exceeded in number those for any previous year, the list including 25 furnaces, as compared with 10 a year ago. These 25 furnaces represent a capacity of about 4,175,000 tons of pig iron a year. In 1916, five new furnaces were blown in, adding about 800,000 tons capacity.

Total capacity of new blast furnaces blown in recent years is as follows:

Year.	Gross Tons.
1905	1,292,000
1906	1,135,000
1907	2,065,000
1908	1,188,000
1909	1,930,000
1910	1,794,000
1911	565,000
1912	1,000,000
1913	550,000
1914	None
1915	530,000
1916	800,000

The following table lists the new furnaces and those now under construction.

Company	Completed 1916.	Under Construction 1917.
Inland Steel Co.	....	1
Whitaker-Glessner Co.	....	1
Republic Iron & Steel Co.	....	1
Worth Brothers Co.	....	1
Cambria Steel Co.	1	2
Corrigan, McKinney & Co.	3	1
United Furnaee Co.	1	....
Sloss-Sheffield Iron & Steel Co.	....	1
Ford Motor Co.	....	2
Bethlehem Steel Co.:		
Sparrows Point	....	4
Steelton Plant	....	3
United States Steel Corporation:		
Indiana Steel Co.	....	4
Gary Tube Co.	....	4
Donner Steel Co.	....	1
Total	5	26

Steel

Steel production for the year amounted to 42,773,680 tons. Steel outputs of the United States for a number of years past are given in the following table:

STEEL PRODUCTION FOR 13 YEARS
(In tons of 2240 lb.)

	Acid.								Basic.		Total.
	Converter.		Open-hearth.		Crucible, etc.		Total.		Open-hearth.		
	Tons.	P.c.	Tons.	P.c.	Tons.	P.c.	Tons.	P.c.	Tons.	P.c.	Tons.
1904	7,859,140	56.7	801,799	5.8	92,581	0.7	8,753,520	63.2	5,106,367	36.8	13,859,887
1905	10,941,375	54.6	1,155,648	5.8	111,196	0.6	12,208,219	61.0	7,815,728	39.0	20,023,947
1906	12,275,830	52.5	1,321,653	5.6	141,893	0.6	13,739,376	58.7	9,658,760	41.3	23,398,136
1907	11,667,549	49.9	1,269,773	5.5	145,309	0.6	13,082,631	56.0	10,279,315	44.0	23,361,946
1908	6,116,755	43.7	696,304	4.9	69,763	0.5	6,882,822	49.4	7,140,425	50.9	14,023,247
1909	9,330,783	39.0	1,076,464	4.5	130,302	0.5	10,537,549	44.0	13,417,472	56.0	23,955,021
1910	9,412,772	36.1	1,212,180	4.6	177,638	0.7	10,802,590	41.4	15,292,329	58.6	26,094,919
1911	7,947,854	33.6	912,718	3.8	129,602	0.4	8,990,174	37.8	14,685,932	62.2	23,676,106
1912	10,327,901	33.4	1,139,221	3.6	142,679	0.4	11,609,801	37.2	19,641,502	62.8	31,251,303
1913	9,545,706	30.5	1,255,305	4.0	155,237	0.5	10,956,248	35.0	20,344,626	65.0	31,300,874
1914	6,220,846	26.5	903,555	3.8	117,500	0.5	7,241,901	30.8	16,271,129	69.2	23,513,030
1915	8,287,213	25.8	1,370,377	4.3	184,721	0.6	9,842,311	30.6	22,308,725	69.4	32,151,036
1916	11,059,039	25.8	1,798,769	4.2	298,610	0.7	13,156,418	30.7	29,616,658	69.3	42,773,680

Included in the 29,616,658 tons of basic open-hearth steel ingots and castings produced in 1916 are 3,436,457 tons of duplex steel ingots and castings which were made from metal partly purified in Bessemer converters and finally purified in basic open-hearth steel furnaces, against 1,781,491 tons in 1915, an increase of 1,654,966 tons, or 92.9 per cent. In 1914, the production was 835,690 tons and in 1913, 2,210,718 tons.

The following table gives the annual output of the important iron and steel forms, for recent years:

	1912.	1913.	1914.	1915.	1916.
Rails	3,327,915	3,502,780	1,945,095	2,204,203	2,854,518
Plates and sheets	5,875,080	5,751,037	4,719,246	6,077,694	7,453,980
Wire rods	2,653,553	2,464,807	2,431,817	3,095,907	3,518,746
Structural shapes	2,846,487	3,004,972	2,031,124	2,437,003	3,029,964
Nail plate	45,331	37,503	38,573	31,929	30,088
Bars, skelp, and all other forms	9,908,475	10,030,144	7,204,444	10,546,188	15,493,093
	24,656,841	24,791,243	18,370,196	24.392,924	32,380,389

Rails.—The total production of steel rails in the United States in 1916 was 2,854,518 gross tons, against 2,204,203 tons in 1915, an increase of over 29 per cent. Below is given the record of rail production for the period 1907 to 1916, according to process of manufacture:[1]

PRODUCTION OF ALL KINDS OF RAILS

Years, Rails.	Open-hearth Steel.	Bessemer Steel.	Re-rolled Steel.*	Electric Steel.	Iron.	Total.
1907	252,704	3,380,025	....	....	925	3,633,654
1908	571,791	1,349,153	....	....	71	1,921,015
1909	1,256,674	1,767,171	....	†	....	3,023,845
1910	1,751,359	1,884,442	....	†	230	3,636,031
1911	1,676,923	1,053,420	91,751	462	234	2,822,790
1912	2,105,144	1,099,926	119,390	3,455	....	3,327,915
1913	2,527,710	817,591	155,043	2,436	....	3,502,780
1914	1,525,851	323,897	95,169	178	....	1,945,095
1915	1,775,168	326,952	102,083	....	....	2,204,203
1916	2,269,600	440,092	144,826	....	....	2,854,518

* Re-rolled from old steel rails and renewed rails which the manufacturers could not classify as Bessemer or open-hearth. Included with Bessemer and open-hearth steel rails to 1910. † Small tonnages rolled in 1909 and 1910 but not included with Bessemer and open-hearth rails for these years.

Girder and high T-rails for electric and street railways are included in the figures given above. For recent years the tonnage was as follows: 1912, 174,004; 1913, 195,659; 1914, 136,889; 1915, 133,965; 1916, 127,410 gross tons.

The total production of rails as given above includes, in addition to new rails rolled during the year, rails re-rolled from defective rails and from old rails. The total of renewed or re-rolled rails so included is given in gross tons in the following table.

PRODUCTION OF RENEWED AND RE-ROLLED RAILS, 1911–1916

Years,	Re-rolled from New Seconds, New Defective Rails, etc.			Rolled from Old Rails.	Total Re-rolled.
	Open-hearth.	Bessemer.	Total.		
1911	2,631	19,379	22,010	91,751	113,761
1912	13,140	29,446	42,586	119,390	161,976
1913	13,052	30,741	43,793	155,043	198,836
1914	13,538	13,234	26,772	95,169	121,941
1915	6,477	2,652	9,129	102,083	111,212
1916	1,711	2,149	3,860	144,826	148,686

[1] *Bull.* 2 (1917), Amer. Iron and Steel Inst.

WEIGHT OF ALL KINDS OF RAILS

Years—Gross Tons.	Under 45 Lb. per Yard.	45 Lb. and Less than 85.	85 Lb. and Less than 100.	100 Lb. and over.	Total Gross Tons.
1907	295,838	1,569,985	1,767,831		3,633,654
1908	183,869	687,632	1,049,514		1,921,015
1909	255,726	1,024,856	1,743,263		3,023,845
1910	260,709	1,275,339	2,099,983		3,636,031
1911	218,758	1,067,696	1,536,336		2,822,790
1912	248,672	1,118,592	1,960,651		3,327,915
1913	*270,405	†967,313	2,265,062		3,502,780
1914	*238,423	†309,865	868,104	528,703	1,945,095
1915	*254,102	†518,291	742,816	688,995	2,204,203
1916	*295,535	†566,791	1,225,341	766,851	2,854,518

* Include rails under 50 lb. † Include 50 lb. and less than 85 lb.

Included above is the annual production of alloy-treated rails, shown separately in the following tables. The tonnage of rails so treated was first determined in 1909.

PRODUCTION OF ALLOY-TREATED STEEL RAILS, 1909–1916

Years.	Total Production, Gross Tons.	Production by Alloys.		Production by Processes.	
		Titanium.	Other Alloys.	Open-hearth and Elect.	Bessemer.
1909	49,395	35,945	13,450	13,696	35,699
1910	257,324	256,759	565	27,389	229,935
1911	153,989	152,990	999	38,539	115,450
1912	149,267	141,773	7,494	40,393	108,874
1913	59,519	47,655	11,864	33,567	25,952
1914	27,937	23,321	4,616	27,447	490
1915	24,970	21,191	3,779	24,367	603
1916	28,562	26,493	2,069	27,675	887

Rolled Iron and Steel.—In 1916, the production of all kinds of iron and steel rolled into finished forms (including blooms, billets, and axle blanks rolled for forging purposes and semi-finished products which were rolled for export in that year) shows an increase of 7,987,465 tons, or 32.7 per cent., as compared with the output in 1915.

TOTAL PRODUCTION OF ALL KINDS OF FINISHED ROLLED IRON AND STEEL, 1907–1916

Years.	Iron and Steel Rails.	Plates and Sheets.	Nail Plate.	Wire Rods.	Structural Shapes.	All Other Finished Rolled Products.	Total, Gross Tons.
1907	3,633,654	4,248,832	52,027	2,017,583	1,940,352	7,972,374	19,864,822
1908	1,921,015	2,649,693	45,747	1,816,949	1,083,181	4,311,608	11,828,193
1909	3,023,845	4,234,346	63,746	2,335,685	2,275,562	7,711,506	19,644,690
1910	3,636,031	4,955,484	45,294	2,241,830	2,266,890	8,475,750	21,621,279
1911	2,822,790	4,488,049	48,522	2,450,453	1,912,367	7,316,990	19,039,171
1912	3,327,915	5,875,080	45,331	2,653,553	2,846,487	9,908,475	24,656,841
1913	3,502,780	5,751,037	37,503	2,464,807	3,004,972	10,030,144	24,791,243
1914	1,945,095	4,719,246	38,573	2,431,714	2,031,124	7,204,444	18,370,196
1915	2,204,203	6,077,694	31,929	3,095,907	2,437,003	10,546,188	24,392,924
1916	2,854,518	7,453,980	30,088	3,518,746	3,029,964	15,493,093	32,380,389

Rolled blooms and billets for forging purposes are included above, while semi-finished products rolled for export are included for 1912 and subsequent years.

In new work initiated or planned, representing additions to steel-making capacity, the year 1916 exceeded all previous records. It also reached a new high figure in the amount of new open-hearth capacity completed and put in operation within the year.

PRODUCTION OF THE U. S. STEEL CORPORATION
Including Tennessee C., I., & Ry. Company

	1911.	1912.	1913.	1914.	1915.	1916.
	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.
Iron Ore Mined—						
From Marquette Range	560,685	551,575	583,266	496,896	618,108	647,132
From Menominee Range	1,105,044	995,401	980,346	874,909	939,304	996,983
From Gogebic Range	1,264,734	1,497,950	1,871,700	1,469,601	1,277,419	2,369,460
From Vermillion Range	1,182,075	1,301,663	1,301,163	1,112,854	1,273,825	1,314,002
From Mesabi Range	14,581,530	20,001,953	21,634,206	10,894,463	17,209,664	24,928,039
In Southern Region	1,239,563	2,079,907	2,367,770	2,186,258	2,351,356	3,099,553
Total	19,933,631	26,428,449	28,738,451	17,034,981	23,669,676	33,355,169
Coke Manufactured	12,120,212	16,719,387	16,663,480	11,163,914	14,500,818	18,901,962
Coal Mined, not used in making coke	5,290,671	5,905,153	6,705.381	5,271,911	5,828,278	6,162,340
Limestone Quarried	4,835,703	6,124,541	6,338,509	4,676,479	5,795,925	7,023,474
Blast Furnace Products—						
Pig iron	10,593,726	13,990,329	13,879,706	9,909,062	13,517,598	17,412,049
Spiegel	66,435	53,829	65,236	25,397	7,175	31,486
Ferro-manganese and Silicon	84,736	142,006	135,788	117,998	116,735	164,102
Total	10,744,897	14,186,164	14,080,730	10,052,457	13,641,508	17,607.637
Steel Ingot Production—						
Bessemer ingots	5,055,696	6,643,147	6,131,809	4,151,510	5,584,198	7,273,766
Open-hearth ingots	7,697,674	10,258,076	10,524,552	7,674,966	10,792,294	13,636,823
Total	12,753,370	16,901,223	16,656,361	11,826,476	16,376,492	20,910,589
Rolled and Other Finished Products for Sale—						
Steel rails	1,568,028	1,857,407	1,927.745	979,907	1,129,832	1,533,681
Blooms, Billets, Slabs, Tinplate Bars	874,474	1,103,752	1,108,147	921,826	1,404,443	1,881,526
Plates	630,512	1,076,308	....	689,241	974,741	1,332,262
Heavy Structural Shapes	547,186	898,537	998,624	613,739	726,082	1,029,682
Merchant Steel, Skelp, Hoops, Bands	1,221,606	1,910,512	2,024,192	1,423,740	2,118,366	2,715,277
Tubing and Pipe	863,670	1,111,138	1,186,740	818,435	919,280	1.338,892
Rods	118,302	196,720	174,478	164,153	261,036	278,197
Wire and Products of Wire	1,613,754	1,629,717	1,432,182	1,380,376	1,771,945	2,004,494
Sheets—Black, Galvanized and Tin-plate	1,079,046	1,508,607	1,280.537	1,075,419	1,368,178	1,786,642
Finished Structural Work	518,399	599,301	652,363	521,225	476,896	557 953
Angle and Splice Bars and Joints	160,855	192,488	256,676	129,849	190,758	277,271
Spikes, Bolts, Nuts and Rivets	60.380	83,426	86,465	62,133	74,289	95,096
Axles	52,046	142,367	159,075	64,662	95,476	173,530
Sundry Iron and Steel Products	167,984	196,339	245,439	117,159	251,317	456,289
Total	9,476,248	12,506,619	11,532,663	9,014,512	11,762,639	15,460,792
Spelter	28,333	31,318	30,424	28,031	32,031	55,898
Copperas (Sulphates of Iron)	28,381	35,215	33,829	30,212	35,377	46,263
Universal Portland Cement (Bbl.)	7,737,500	10,114,500	11,197,000	9,116,000	7,648.658	10,425,600

The new steel-making capacity provided during 1916 is nearly three times as large as that finished in 1915, as reported in our review a year ago. The present summary shows 103 open-hearth furnaces completed in 1916, with an annual capacity of 4,205,000 gross tons, while in 1915 the total completed was only 29, with an annual capacity of 1,405,000 tons.

Furnaces under construction, many of which will be completed in 1917, number 72, which compares with 91 a year ago. Although the number thus is less, the total estimated annual capacity is larger, or 4,515,000 tons for the 72 furnaces, as compared with 4,265,000 tons for the 91 furnaces, due to the fact that several large duplexing plants with new converters are now coming forward.

In the list of furnaces under construction and projected, the Steel Corporation is represented by six 75-ton furnaces at the plant of the National Tube Co., Lorain, Ohio; by a duplexing plant at the Indiana Steel Co., Gary, Ind., consisting of two 100-ton tilting open-hearth furnaces and two 25-ton Bessemer converters; by a new duplexing plant at the South works of the Illinois Steel Co., South Chicago, consisting of two 100-ton open-hearth furnaces, and two 25-ton Bessemer converters, and by one 100-ton tilting open-hearth furnace at the same plant to supply hot metal to the two new 20-ton Heroult electric furnaces.

In this list the Bethlehem Steel Corporation is credited with the installation at its Saucon plant at South Bethlehem, Pa., of two 200-ton tilting open-hearth furnaces, a 25-ton Bessemer converter and a new 1300-ton mixer with all auxiliary equipment; with one 200-ton tilting furnace and a 20-ton converter at its Steelton plant, Steelton, Pa., and with a new duplexing unit at the Maryland steel plant, Sparrows Point, Md., consisting of four 200-ton tilting furnaces, four 30-ton converters and two 1300-ton and one 250-ton hot metal mixers.[1]

The net income for the year was $201,835,584.83 as compared with $44,260,374.46 in 1915. The gross earnings amounted to $1,231,473,779 as compared with $726,683,589 in 1915.

Imports and Exports.—United States imports and exports of iron and steel are tabulated below. Exports were heavy in practically all lines, and reached record figures in those products entering into the manufacture of munitions or utilized for war purposes.

UNITED STATES EXPORTS OF DOMESTIC IRON AND STEEL
(In tons of 2240 lb.)

	1909.	1910.	1911.	1912.	1913.	1914.	1915.	1916.
Pig iron	61,999	127,385	120,799	272,676	277,648	114,423	224,509	612,241
Billets, blooms, etc.	104,862	58,230	234,267	294,818	91,847	50,496	560,704	1,508,727
Bars	87,960	125,606	141,033	230,139	228,331	128,228	465,720	848,479
Rails	299,540	353,180	420,874	446,473	460,553	174,680	391,379	540,349
Sheets and plates	180,048	274,516	372,373	546,968	463,414	280,090	419,637	515.462
Structural steel	90,830	146,721	223,493	288,164	403,264	182,395	232,139	301,649
Wire	149,341	171,928	229,316	244,711	190,282	180,395	473,583	683,025
Wire-rods	20,142	22,869	22,641	65,470	61,636	61,853	165,014	158,284
Nails and spikes	48,055	61,201	77,833	92,497	62,726	49,622	118,349	191,131
Pipe and fittings	162,140	155,728	197,597	249,856	301,784	199,618	176,884	228,573

[1] *Iron Age*, Jan. 4, 1917.

UNITED STATES IMPORTS OF IRON AND STEEL
(In tons of 2240 lb.)

	1908.	1909.	1910.	1911.	1912.	1913.	1914.	1915.	1916.
Pig iron......	92,202	174,988	237,233	148,459	129,325	165,450	138,903	89,836	135,349
Billets, blooms, etc...	12,112	19,913	46,578	29,205	18,702	26,675	49,188	14,998	26,142
Scrap iron and steel..	5.090	63,504	72,764	17,272	23,612	44,154	34,849	79,982	116,039
Bars................	19,672	19,206	43,692	26,729	26,112	28,243	15,015	8,474	7,701
Rails...............	1,719	1,513	....	....	3,780	10,408	22,571	78,525	26,299
Wire-rods...........	11,208	10,544	20,374	15,483	15,070	16,097	6,954	5,316	4,130
Tinplate............	58,320	62,593	66,640	14,099	2,052	20,680	15,411	2,350	1,007

Electric Steel[1]

Progress in 1916 in the electric-steel industry of the United States and of the world has been phenomenal. It has exceeded the expectations of many. In this development the United States has taken the leading part, and maintains its supremacy by an increased margin over that of a year ago.

The production of electric steel in the United States is as follows:

1909	13,762
1910	52,141
1911	29,105
1912	18,309
1913	30,180
1914	24,009
1915	69,412
1916	168,918

On Jan. 1, 1916, 73 electric furnaces were operating or contracted for in the steel industry in the United States and 8 in Canada. At the opening of 1917 these totals have increased to 136 in the United States and 19 in Canada, or 155 in both countries. This is an increase of 74 furnaces, or 47.7 per cent.

Two years ago, Jan. 1, 1915, a list of the furnaces for the entire world showed a total of 213. In 1915, the electric-steel industry made unusual strides, stimulated by the rising tide of war demand for steel, and on Jan. 1, 1916, there were 303 electric furnaces in the world's steel industry, a gain of 90 in the year. This remarkable showing has been surpassed in 1916, in spite of the war, or rather, in most cases, because of it. New furnaces, installed or contracted for in 1916 were 168, making the total in the world's steel industry 471 on Jan. 1, 1917—an increase of 35.6 per cent.

Progress in the United States in 1916.—There has been an increase of 63 furnaces in the United States in 1916, or 46.3 per cent. The total is now 136 as against 73 on Jan. 1, 1916. In Canada the total reported Jan. 1, 1917, is 19 as compared with 8 on Jan. 1, 1916. Some of these, however, were in operation in 1915, but were reported later. The increase in the two countries in 1917 has been 47.7 per cent.

The Heroult furnace continues to take the commanding position in

[1]*Iron Age*, Jan. 4, 1917, with some additions.

the expansion. On Jan. 1, 1915, there were but 19 furnaces of this type in the United States and Canada; on Jan. 1, 1916, the total was 43, but now it is 84 or a growth of nearly 100 per cent. in one year. A significant feature of the past year's development is that only 9 of the new installations in 1916 were in the steel-casting industry, the majority going into tool and special steel plants, 5 alone to make seamless tubes. In 1915 the growth was largely in the steel-casting industry. The outstanding feature is the decision of the United States Steel Corporation last year to install for itself three 20-ton furnaces, two at the Illinois Steel Co., South Chicago, and one for the Carnegie Steel Co. at Duquesne, Pa. The last-named is now operating and is capable of making 10 heats per day from hot metal. The two at South Chicago will be operating early this year and, with the two 15-ton Heroult furnaces already making steel there, will go to make the largest electric-steel plant in the world.

The installations of Snyder furnaces have increased from 12 in the United States a year ago to 19, with an additional one in Canada, making the total there 3. The combined total in the two countries is now 22 against 14 on Jan. 1, 1916. The use of the furnace in other lines is important, as in the brass, tungsten, and antimony industries, while four furnaces are making ferro-silicon for the British Admiralty in England. Three furnaces are operating in Chile in the chemical industry.

The Rennerfelt furnace has made rapid strides since its appearance in the United States steel industry late in 1915. The total in the United States is now 13 instead of 2 a year ago. The expansion has not been confined to the steel industry, 2 being credited to the brass industry in this country, 11 to ferro-tungsten and 1 to the aluminium alloy industry.

The Grönwall-Dixon furnace is also advancing rapidly as a steel-making unit. A year ago only 1 was credited to the United States, but now there are 8 in the United States and 1 in Canada. A description of this furnace was published in the *Iron Age*, Sept. 7, 1916. One furnace in the brass industry has been contracted for in 1916—a 500-lb. furnace at the Cleveland Brass Mfg. Co., Cleveland, Ohio.

The increase in furnaces of a special type in the United States in the past year has been 5, the total now being 7 against 2 a year ago. Prominent among these is the Greene electric-steel furnace, operating basic and making soft steel and manganese-steel castings at the Olympic Steel Works, Seattle, Wash. It is built under the designs of the Greene Process Metal Co. of St. Louis, and operates under the "Greene slag" process of melting. A special furnace of the company's own design is melting alloys for the Chrome Steel Works, Chrome, N. J. The Crafts furnace, a special induction type, is nearly ready to operate in Cleveland, Ohio. It was described in the *Iron Age*, Sept. 18, 1913.

It is probable that two more Girod 10-ton furnaces will be installed by the Bethlehem Steel Co. in 1917.

The apparent net increase of 63 furnaces in the United States in 1916 is really less than the actual, for several of different types, about 10, were dropped during the year.

Developments in Europe.—In some countries, notably Great Britain, the war has created such a demand for special castings and shell steel that this has had to be met by electric steel. In this way progress in Europe has been largely determined by the war.

The greatest expansion has been in Great Britain (England). On Jan. 1, 1916, there were 46 furnaces credited to that country against only 16 on Jan. 1, 1915. Our present analysis shows 88 on Jan. 1, 1917, an increase of 42 or nearly 100 per cent. Of this increase 14 are Heroult, making the total of this type 34 in that country. Vicker's Sons & Maxim, Ltd., in 1916, added a 2½- or a 3-ton Heroult furnace, making its total 4; Thomas, Firth & Sons, two 7-ton, two 6-ton, a 2½- and a 1-ton furnace, making its total 8; Samuel Osborn, two 1½-ton furnaces, making its total 3, while Hadfield's, Ltd., made the company's total 10 furnaces by adding four 8-ton, one 3½-ton and one 1½-ton furnace. The Snyder has increased its steel-making furnaces there from 3 to 6 in the year, the Grönwall or Electro-Metals from 12 to 14 and the Rennerfelt from 4 to 7.

A new competitor in the British field appeared in 1916. It is the Greaves-Etchells furnace. It was announced in the *Iron Age,* Nov. 30, 1916, and was originally designed to meet the special requirements of the Sheffield steel industry. Three-phase current is used, three single-phase transformers are connected with meshed primaries. To date 20 of these furnaces have been installed or contracted for in England.

In France, 8 Heroult furnaces have been added to the total of the country, which is now 29 against 21 a year ago. Of these 19 are Heroult, 7 Girod, 2 Stassano and 1 Rennerfelt. The war has probably retarded the industry in this country rather than helped it.

In Sweden, the total has advanced from 23 on Jan. 1, 1916, to 40 on Jan. 1, 1917. There is one more Heroult in that country and 14 more Rennerfelts making steel. Two Grönwall-Dixon furnaces have been introduced in 1916. The total in Norway has been brought to 9 as against 6 a year ago by the introduction of 3 more. Rennerfelt has increased its total from 4 to 7.

Because of the war, complete information regarding the electric-steel industry of Germany and Austria-Hungary has been impossible. The table at the end of this review shows 52 furnaces in Germany instead of 53 a year ago, but this is due to the discontinuance of one Girod furnace. In the column of induction furnaces and opposite the item, "location not given," 12 furnaces are credited. It is probable that these are largely in Germany. The estimate is based on that of German representatives in this country. It is not at all unlikely that the German total is considerably in excess of 52, for that country's electric-steel output is now at the rate of nearly 200,000 tons per year as against 130,000 tons in 1915 and 90,000 tons in 1914.

The Heroult leads in the introduction of furnace types in Europe. On Jan. 1, 1916, there were 72 Heroult furnaces in Europe; now there are 97. A year ago there were 33 Rennerfelts across the seas and now there are 57. The Snyder furnace is credited with 2 more in Europe than a year ago, when it was 4, and the Grönwall with 20 instead of 14.

Progress in the World.—While the United States led the world for the first time a year ago with 73 electric furnaces, displacing Germany, this country now has the commanding lead of 136 furnaces. In the year Great Britain has displaced Germany in second place with 88 furnaces on Jan. 1, 1917, against 46 on Jan. 1, 1916. Germany is easily third with probably more than 52, while Sweden still ranks fourth with 40. France and Italy are next with 29 each. The gain in the world's total in 1916 was 168 or 35.6 per cent., or a total of 471 to 303 a year ago.

From the world's point of view, a striking development has been the increase in the use of certain types. The Heroult furnace leads in the total of new installations. Its total a year ago in the world was 115 of this type; now it is 181, a gain of 36.

Rennerfelt furnaces a year ago were 35 in the world's steel industry; now there are 70. There are also 11 in the brass and other industries in Europe and 14 in such industries in the United States.

The Snyder furnace, which had 18 in the steel industry a year ago, now is credited with 28; besides these there are about 10 in other industries.

The Grönwall-Dixon, Grönwall, or Electro-Metals furnace, which a year ago numbered 15 in the world, is now credited with 29, besides the one small furnace (500-lb.) at the plant of the Cleveland Brass Mfg. Co., Cleveland, Ohio.

The induction type is credited with a gain of 12 in the world or 47 against 35 on Jan. 1, 1916. More complete information after the war may increase this.

In 3½ years, or since this review was first published on July 1, 1913, the world's electric-steel industry has more than tripled, advancing from a total of 149 to 471. In the same period that of the United States has increased from 19 furnaces to 136, or more than seven times. From the point of view of production the United States probably also leads, that for 1916 without doubt exceeding any other country.

TABLE OF TYPES OF ELECTRIC FURNACES BY COUNTRIES OF THE WORLD OPERATING OR CONTRACTED FOR ON JAN. 1, 1917.
With Totals for 1916, 1915, 1913, and 1910.

	Heroult.	Girod.	Induction.	Stassano.	Keller.	Chapelet.	Nathusius.	Snyder.	Wile.	Rennerfelt.	Grönwall-Dixon.*	Greene.	Special.	Greaves-Etchells.	Total Jan. 1, 1917.	Total Jan. 1, 1916.	Total Jan. 1, 1915.	Total July 1, 1913.	Total March, 1910.
Germany and Luxemburg	19	5	19	2	3	..	4	..	..	..	..	..	..	..	52	53	46	34	30
Austria-Hungary	10	2	3	2	..	..	..	..	..	1	..	..	..	..	18	18	18	10	10
Switzerland	1	2	..	..	..	..	..	..	..	1	..	..	..	..	4	4	3	2	2
Italy	4	..	2	13	5	5	..	..	..	..	..	..	..	..	29	22	22	20	12
France	19	7	2	..	..	..	..	..	..	1	..	..	..	..	29	21	17	13	23
Great Britain	34	1	2	4	..	..	..	6	..	7	14	..	..	20	88	46	16	16	7
Belgium	2	1	..	..	..	..	..	..	..	..	..	..	..	..	3	3	3	3	3
Russia	3	1	1	2	..	..	..	..	..	7	2	..	..	..	16	11	9	4	2
Sweden	3	..	1	..	..	..	..	..	..	34	2	..	..	..	40	23	18	6	5
Norway	..	..	2	..	..	..	..	..	1	6	..	..	..	..	9	6	2	3	
Spain	..	..	1	..	..	..	..	..	..	..	1	..	..	..	2	2	1	1	
Japan	1	..	1	..	..	..	..	..	..	..	..	..	..	..	2	1	1	1	
Mexico	..	..	1	..	..	..	..	..	..	..	..	..	..	..	1	1	1	4	3
Australia	..	..	..	..	..	..	..	..	..	..	1	..	..	..	1	1	1		
Chile	..	..	..	..	..	..	..	..	..	..	..	..	..	..	...	1			
Roumania	1	..	..	..	..	..	..	..	..	..	..	..	..	..	1				
Location not given	..	..	12	..	..	..	..	..	..	..	..	..	9	..	21	9	12		
Total outside the United States and Canada	97	19	47	23	8	5	4	6	1	57	20	..	9	20	316	222	170	118	101
United States	79	4	3	1	..	..	..	19	1	13	8	1	7	..	136	73	41	19	10
Canada	5	..	..	..	..	..	..	3	..	..	1	..	10	..	19	8	2	3	3
Total in U. S. and Canada	84	4	3	1	..	..	..	22	1	13	9	1	17	..	155	81	43	22	13
Grand Total in World	181	23	50	24	8	5	4	28	2	70	29	1	26	20	471	303	213	140	114

* Electro Metals in Great Britain.

Foreign Countries

The world's production of iron and steel, so far as data are available for the different countries, is noted in the accompanying tables:

PIG-IRON PRODUCTION OF THE WORLD
(In metric tons)

Year.	Austria-Hungary.	Belgium.	Canada.	France.	Germany.	Italy.	Russia.
1907	1,405,000	1,427,940	590,444	3,588,949	13,045,760	32,000	2,768,220
1908	1,650,000	1,206,440	572,284	3,391,150	11,813,511	112,924	2,748,000
1909	1,958,786	1,632,350	686,886	3,632,105	12,917,653	207,800	2,871,332
1910	2,010,000	1,852,090	726,471	4,032,459	14,793,325	215,000	3,042,046
1911	2,095,000	2,046,280	832,376	4,426,469	15,280,527	302,931	3,521,000
1912	2,312,689	2,301,290	920,636	4,871,992	17,852,571	379,987	4,197,638
1913	2,369,864	2,484,690	1,024,424	5,311,316	19,291,920	426,775	4,548,376
1914	2,020,000	1,560,000	710,481	5,025,000	14,389,547	385,114	4,261,008
1915	1,960,000	....	828,920	4,750,000	11,790,199	377,510	3,696,560
1916	....	....	1,060,787	....	....	454,923	....

Year.	Spain.	Sweden.	United Kingdom.	United States.	All Other Countries.	Total.
1907..........	385,000	603,100	10,082,638	26,193,863	556,900	60,679,814
1908..........	403,500	563,300	9,438,477	16,190,994	550,000	48,640,419
1909..........	389,000	443,000	9,818,916	26,108,199	550,000	61,217,064
1910..........	367,000	604,300	10,380,723	27,636,687	525,000	66,210,720
1911..........	408,667	633,800	9,718,638	24,027,940	535,000	63,210,694
1912..........	403,243	701,900	8,751,464	30,202,568	540,000	73,529,929
1913..........	424,773	735,000	10,481,917	31.482,406	550,500	79,395,472
1914..........	435,000	635,100	9,005,898	23,721,115	495,000	62,844,609
1915..........	419,000	767,600	8,793,659	30,414,817	480,000	64,515,928
1916..........	....	....	9,047,983	40,092,043	....	....

STEEL PRODUCTION OF THE WORLD
(In metric tons)

Year.	Austria-Hungary.	Belgium.	Canada.	France.	Germany.	Italy.	Russia.
1906.....	1,195,000	1,185,660	580,056	2,371,377	11,135,085	109,000	2,431,000
1907.....	1,195,500	1,183,500	641,369	2,677,805	12,063,632	115,000	2,600,000
1908.....	2,025,182	1,065,500	534,631	2,727,717	10,480,349	537,000	2,628,000
1909.....	1,969,538	1,370,000	684,677	3,034,571	12,049,834	661,600	3,071,000
1910.....	2,188,371	1,449,500	745,971	3,506,497	13,698,638	635,000	3,479,000
1911.....	2,363,008	2,192,630	800,504	3,680,613	15,019,333	736,000	3,870,000
1912.....	2.785,105	2,515,040	868,811	4,078,352	17,301,998	801.951	4,498,000
1913.....	2,682,619	....	1,060,503	4,419,241	18,958,819	911,500	4,827,000
1914.....	2,190,759	....	751,738	....	15,619,719	....	....
1915.....	2,686,226	....	918,926	....	13,237,646	....	4,018,000
1916....	....	....	1,319,187	....	....	....	....

Year.	Spain.	Sweden.	United Kingdom.	United States.	All Other Countries.	Total.
1906........	289,732	351,900	6,566,316	23,772,506	420,000	49,635,998
1907........	297,684	443,000	6,627,764	23,733,391	405,000	51,273,340
1908........	301,360	427,100	5,380,912	14,247,619	300,000	44,359,522
1909........	309,479	310,600	5,976,322	24,338,302	325,000	53,499,974
1910........	316,301	468,600	6,477,110	26,512,437	315,000	58,656,312
1911........	322,981	456,500	6,565,645	24,054,918	325,000	58,275,701
1912........	317,880	508,300	6,904,546	31,751,324	....	....
1913........	365,118	582,700	7,787,264	31,822,555	....	....
1914........	....	500,600	7,918,243	23,904,914	....	....
1915........	....	588,800	8,687,670	32,686,887	....	....
1916........	....	....	9,396,292	43,486,574	....	....

Australia.—The iron ore deposits worked by the Broken Hill Proprietary are on Iron Knob and Iron Monarch hills, 1160 ft. above sea level and 34 miles northwest of the company's port at Hummock Hill on Spencer Gulf, nearly opposite Port Pirie, South Australia. There is no natural harbor and the steamers which carry the ore to Newcastle, New South Wales, have to load from a jetty 2290 ft. in length.[1] The works at Newcastle are now thoroughly established. Additions are in hand, and the prospects are excellent for the industry. The erection of these works has proved to be of national importance, both for the direct purpose of the war and also for great works of a national character

[1] *Min. Mag.*, Dec., 1916.

—*e.g.*, manufacture of steel rails for the transcontinental railway—and it is certain that many subsidiary industries will grow up in close proximity to the iron and steel furnaces. As the outcome of many conferences with representatives of the scrap iron and steel industries, methods have been devised for the classification and valuation of these materials, based upon definite standards. This work should prove of great benefit to the producers of scrap iron and steel, and also to the mills consuming same. Practically the whole of these scrap metals will be worked up in Australia, leaving little or nothing for export to China—which in the past has been the principal market. Negotiations are well advanced dealing with ferro-alloys, and a market has been secured for tungsten, scheelite, and molybdenite.[1]

Belgium.—Owing to the disorganization wrought by the war, no statistics are available. Production of pig iron and steel in recent years is given below:

PIG-IRON PRODUCTION IN BELGIUM
(In metric tons)

	1907.	1908.	1909.	1910.	1911.	1912.	1913.
Foundry iron....	100,020	76,190	89,960	(*a*) 83,710	(*a*) 60,630	(*a*) 96,620	27,665
Forge iron.......	226,430	127,630	156,590	115,760	102,690	66,940	92,825
Steel pig........	1,101,490	1,002,620	1,386,800	1,652,620	1,882,960	2,137,730	2,356,040
Total.........	1,427,940	1,206,440	1,632,350	1,852,090	2,046,280	2,301,290	2,476,530

(*a*) Includes special cast irons.

STEEL PRODUCTION IN BELGIUM

	Bessemer.	Open-hearth.	Castings.	Total.
1905	1,095,880	104,550	26,680	1,227,110
1906	1,277,010	118,130	45,720	1,440,860
1907	1,289,750	176,960	54,900	1,521,610
1908	1,070,840	127,160	51,620	1,250,620
1909	1,470,400	109,950	52,040	1,632,390
1910	1,755,500	136,660	52,660	1,944,820
1911	1,971,760	156,410	64,460	2,192,630
1912	2,252,380	190,040	72,620	2,515,040

Brazil.[2]—The Minas Geraes ore is predominately hematite—hard, dense and specular—having, according to Harder, the following composition:

	Per Cent.
Iron	69.65
Phosphorus	0.0125
Silica	0.24
Combined water	0.38

There is, of course, much ore inferior to this, but even the poorest (*canga*) ranges between 50 and 65 per cent. iron and 0.1 and 0.3 per cent. phos-

[1] *Min. Jour.*, Oct. 21, 1916.
[2] F. L. Garrison, *Min. Sci. Press.*

phorus. In addition Harder gives a table of average analyses of iron and phosphorus for the different grades of ore. At present heavy shipments can not be made because the existing railways were not designed for such traffic and there are no proper storage and shipping facilities at Rio de Janeiro and Victoria, the two seaports through which this traffic would have to go.

Canada[1].—Mining operations have been confined to the Helen and Magpie mines of the Algoma Steel Corporation in the Michipicoten district of Ontario, together with a small production of ilmenite at Ivry-on-the-Lake, Quebec, by the Manitou Iron Mining Co. There was also a shipment of concentrates from the concentrator at Trenton, Ont., produced in previous years from ores derived from the Bessemer and Childs mines in Hastings county.

The total shipments in 1916 were 339,600 short tons valued at $814,-044 as compared with 398,112 tons valued at $774,427 shipped in 1915. The 1916 shipment included 109,965 tons of Helen ore, part of which was sent to Magpie for roasting, 210,522 tons of roasted siderite from Magpie, 15,904 tons of magnetite concentrates and 3209 tons of ilmenite. The shipments in 1915 included 205,989 tons of hematite, 132,906 tons of roasted siderite and 59,217 tons of magnetite (including some ores with an admixture of hematite).

In the Great Lakes area the ore prices for 1916 were Old Range Bessemer $4.45 per gross ton; Messabi Bessemer $4.20; Old Range Non-Bessemer $3.70 and Messabi Non-Bessemer $3.55, an increase of 70 cts. over 1915 prices. The 1917 quotations already fixed are $1.50 in advance of those of 1916.

Mine operators reported 140,608 tons of ore exported to the United States and 198,992 tons shipped to Canadian furnaces.

According to the records of the Customs Department exports of iron ore amounted to 161,260 tons valued at $541,779 and imports of iron ore to 2,339,667 tons valued at $4,419,013.

Shipments of iron ore from Wabana mines, Newfoundland, in 1916 by the two Canadian companies operating there were 1,012,060 short tons all of which were shipped to Cape Breton.

In 1915 the total shipments were 868,451 short tons of which 802,128 tons was shipped to Cape Breton and 66,323 tons to England.

The total production of pig iron in 1916, not including the output of ferro-alloys, was 1,169,257 short tons (1,043,979 long tons), valued at $16,750,903 as compared with 913,775 short tons (815,870 long tons), valued at $11,374,199 in 1915, showing an increase of 255,482 tons, or 27.9 per cent.

[1]*Prelim. Rept. Min. Prod. of Can.*, 1916, Dept. of Mines.

The 1916 production was greater than that of any previous year, the second largest production of pig iron having been 1,128,967 short tons in 1913.

The production in Nova Scotia in 1916 was 470,055 tons as against 420,275 tons in 1915, an increase of 49,780 tons or 11.8 per cent. while the production in Ontario was 699,202 tons in 1916 compared with 493,500 tons in 1915, an increase of 205,702 tons, or 41.7 per cent.

Of the total output in 1916, 17,304 tons was made with charcoal as fuel as against 13,692 tons made with charcoal in 1915.

By grades the 1916 production included: basic 953,627 tons; Bessemer 31,388 tons; foundry and malleable, etc., 184,242 tons. The 1915 production included: basic 739,613 tons; Bessemer 29,052; foundry and malleable, etc., 145,110 tons.

The blast-furnace plants operated were the same as in the previous year, viz.: the Dominion Iron & Steel Co. at Sydney, N. S., the Nova Scotia Steel & Coal Co., at North Sydney; The Standard Iron Co. at Deseronto, Ont., the Steel Co. of Canada, at Hamilton, Ont., The Canadian Furnace Co., at Port Colborne, Ont., and the Algoma Steel Corporation at Sault Ste. Marie, Ont.

The production of ferro-alloys in Canada in 1916, chiefly ferro-silicon, but including also ferro-phosphorus and ferro-molybdenum, all made in electric furnaces, was 28,628 tons valued at $1,777,615, as compared with production in 1915 of 10,794 tons valued at $753,404.

The exports during 1916 of pig iron were 23,304 tons, valued at $374,383 or an average per ton of $16.07, and of ferro-silicon and ferro-compounds 22,802 tons valued at $1,352,013, or an average of $59.29 per ton.

The imports during 1916 included 57,337 tons of pig iron valued at $1,128,557, or an average of $19.68 per ton; 793 tons of charcoal pig valued at $16,593, or an average of $20.92, and 45,309 tons of ferro products valued at $1,879,448, or an average of $41.48 per ton, making a total import of pig iron and ferro-alloys of 103,439 tons valued at $3,024,598.

The estimated production of steel ingots and castings in 1916 was 1,454,124 short tons (1,298,325 gross tons) of which 1,423,485 short tons were ingots and 30,639 tons direct steel castings. The total production in 1915 was 1,012,926 short tons, showing an increase in 1916 of over 42 per cent. The 1916 production was greater than that of any previous year the second largest production having been 1,168,993 short tons in 1913.

Of the total production of steel ingots and castings in 1916, about 43,790 short tons (39,098 gross tons) were made in electric furnaces. In

1915 only 61 short tons was reported as having been made in electric furnaces.

Chile.—There has recently been developed in Santiago a steel industry on a small scale, using as raw material the old iron formerly exported to Europe. The high price of steel after the outbreak of the European war led to the domestic manufacture. Great difficulty was experienced at first in finding skilled workmen, until Spaniards were secured from Bilbao, where the steel industry is developed. Chileans were taken on as apprentices, and the force now employed numbers about 100, not including those who collect the old iron. A special foundry had to be built for making the needed machinery, which was turned out after European models, as was also the refining furnace. Chilean coal is being used, which is another item of economy.

The products of the mill include bars, plates, angles, tees, construction steel for concrete buildings, carriage parts, bolts, nuts, nails, horseshoes, tires, etc. The Chilean steel sells for 20 per cent. less than the imported steel. A fair quality has been obtained, and the operating difficulties encountered at first are now being overcome. The demand for steel in Chile is large and increasing, which assures an immediate market for all that can be produced at the Santiago mill.[1] A second project is under way for the installation of an electric furnace for making steel castings.

China (By T. T. Read).—The most notable feature of the year has been the securing of the control of all the best-known and most accessible deposits of iron ore by Japanese companies. The Penhsihu Coal and Iron Co., in Manchuria, now has one blast furnace in operation, producing about 100 tons per day. The larger part of the pig iron goes to the South Manchuria Railway workshops at Dairen, and to the Kawasaki dock yard at Kobe, and the remainder to various points in Japan. This is a joint Chinese-Japanese enterprise. A new iron-ore deposit has been developed by the South Manchuria Railway Co., at Anshanchang, between this point and Dairen, and will soon be equipped to produce. The German-owned properties in Shantung, which were taken over by the Japanese in 1915, have proved disappointing, as the deposits are apparently neither so rich nor so extensive as reported. The Han-Yeh-Ping Iron & Coal Co. iron mines and smelting plant, formerly a Chinese Government enterprise, but now controlled by Japanese, is being provided with larger equipment, but the work seems to proceed slowly, as the company is negotiating for further coal and iron-ore deposits to increase its reserves.

A Japanese company, with a capital of $10,000,000 has taken over the Tao-Chang mine, in Anhwei, and will proceed to develop the mine

[1] *Comm. Rept.*, Nov. 28, 1916.

and build blast furnaces, but the latest reports indicate that this deposit is much smaller than was first reported.

Cuba.—Cuban shipments of ore in 1915 and 1916 were considerably checked because of transportation difficulties. Total shipments to the United States for the year were 716,571 tons, the smallest since 1908. Shipments in recent years were as follows; figures for 1915 and 1914 are estimated:

Year.	Total.	South Coast.	North Coast.
1916	716,571	....	......
1915	830,000	520,000	310,000
1914	850,000	580,000	270,000
1913	1,582,431	1,090,718	491,713
1912	1,397,797	951,621	446,176
1911	1,163,714	775,922	387,792
1910	1,462,498	1,154,798	307,700
1909	936,132	936,132	......
1908	620,836	620,836	......
1907	650,174	650,174	......
1906	640,574	640,574	......

France.—The iron and steel industry of France is largely centered in the war zone, and the demoralization occasioned has left a dearth of statistics for the war period. So far as data are available, the production of iron and steel is noted below:

PIG-IRON PRODUCTION IN FRANCE
(In metric tons)

	1906.	1907.	1908.	1909.	1910.	1911. (a)	1912. (a)	1913.
Foundry	591,275	651,700	695,527	749,247	760,622	836,454	825,682	957,145
Forge	741,571	673,885	543,067	538,053	556,767	586,496	568,164	565,133
Bessemer	149,971	122,046	118,121	118,002	104,966	104,265	117,221	161,464
Basic	1,784,726	1,988,343	1,949,107	2,172,718	2,549,908	2,777,261	3,304,518	3,546,057
Special irons	51,489	152,975	85,328	54,085	60,196	122,113	56,407	81,517
Total	3,319,032	3,588,949	3,391,150	3,632,105	4,032,459	4,426,469	4,871,992	5,311,316

(a) As reported by the Comité des Forges.

IRON AND STEEL PRODUCTION IN FRANCE
(In metric tons)

	1906.	1907.	1908.	1909.	1910.	1911.	1912.	1913.
Wrought iron	747,900	687,249	563,745	519,200	501,100	462,681	(e)450,000	....
Steel ingots	2,436,322	2,766,773	2,727,617	3,034,571	3,506,497	3,680,613	4,078,352	4,419,241
Finished steel	1,454,456	2,261,217	1,894,022	2,043,022	2,684,000	2,638,484	3,028,799	2,993,050

(e) Estimated.

French iron-ore imports in 1916 are given as 627,603 metric tons, as against only 271,159 tons in 1915, and 1,400,000 tons in normal years. Spain furnished 457,273 tons of the 1916 imports and 86,347 tons came

STEEL PRODUCTION IN FRANCE
(Metric tons)

	Bessemer.		Open-hearth.	Crucible and Electric.	Total.
	Acid.	Basic.			
1904	....	1,334,798	745,756	....	2,080,354
1905	119,526	1,345,511	775,247	....	2,240,284
1906	108,037	1,418,525	834,815	....	2,371,377
1907	78,771	1,669,757	1,001,463	16,782	2,766,773
1908	77,581	1,632,296	1,002,798	14,951	2,727,657
1909	76,981	1,853,327	1,080,912	23,351	3,034,571
1910	81,293	2,131,676	1,148,548	28,792	3,390,309
1911	75,158	2,389,352	1,185,345	30,758	3,680,613
1912	73,917	2,664,610	1,320,462	37,363	4,078,352
1913	76,816	2,931,072	1,368,067	43,286	4,419,241

from Italy. Pig-iron and steel imports are given as follows, in metric tons:

	1916.	1915.	1913.
Pig iron	621,978	166,397	32,669
Blooms, billets and bars	1,659,621	567,011	19,379
Wire rods	81,405	63,051	6,903
Plates and sheets	272,791	73,784	13,760
Tin plates	80,619	68,340	19,460
Wire	93,598	46,266	6,088
Rails	142,809	40,658	1,792

Great Britain furnished 551,560 tons of the pig-iron imports in 1916. The very large expansion was due to the manufacture of shells.

Particulars as to the shipments of iron and steel from the French iron districts in German occupation (Briey and Longwy) to Germany and Belgium before and since the war are given as follows in metric tons by the London *Ironmonger* as reported in the *Berliner Börsen Courier:*

	1913, Tons.	1914, Tons.	1915, Tons.
Iron ore to Germany	734,012	356,438	41,913
Iron ore to Belgium (including Antwerp)	1,108,152	696,721	112,371
Pig iron to Belgium	103,537	38,169	6,064
Steel to Belgium	288,288	218,105	4,733

Germany.—Monthly production of pig iron, so far as figures are available, is given below.

	Metric Tons.			
	1913.	1914.	1915.	1916.
January	1,611,345	1,566,505	963,790	....
February	1,493,877	1,445,511	946,191	....
March	1,629,463	1,602,896	1,098,311	....
April	1,588,701	1,534,429	1,012,824	....
May	1,643,069	1,607,193	1,044,107	....
June	1,609,748	1,531,313	1,080,786	....
July	1,648,818	1,564,345	1,138,651	1,134,000
August	1,640,016	586,661	1,158,702	1,145,000
September	1,599,849	580,087	1,174,350	1,117,000
October	1,653,051	729,822	1,215,287	1,161,000
November	1,588,985	788,956	1,192,817	1,101,000
December	1,611,250	853,881	1,165,465	
Total	19,309,172	14,389,547	11,790,199	....

Production of pig iron by kinds for several years past is noted below. Steel pig includes ferro-manganese, spiegeleisen, ferro-silicon, and similar alloys:

PRODUCTION OF PIG IRON IN GERMANY
(In metric tons)

	1908.	1909.	1910.	1911.	1912.	1913.	1914.	1915.
Foundry iron.	2,254,644	2,491,919	2,968,810	2,881,059	3,355,177	3,640,074	2,494,527	2,286,670
Forge iron...	635,228	652,306	644,992	689,881	525,423	489,783	370,257	278,684
Steel pig.....	934,940	1,099,779	1,327,196	1,547,480	2,201,489	2,599,887	1,996,786	1,793,865
Bessemer pig.	361,472	412,118	471,366	377,051	388,855	368,840	237,988	187,522
Thomas pig..	7,627,227	8,261,538	9,338,961	9,785,056	11,397,965	12,193,336	9,289,989	7,243,458
Total......	11,813,511	12,917,653	14,793,325	15,280,527	17,868,909	19,291,920	14,389,547	11,790,199

The following table gives the production according to districts:

PRODUCTION ACCORDING TO DISTRICTS

	Tons, 1913.	Tons, 1914.	Tons, 1915.
Rhenish-Westphalia	8,209,157	6,610,119	5,165,618
Siegerland and Hessen-Nassau	994,927	702,436	789,650
Silesia	994,604	853,957	777,625
North and Central Germany	1,001,321	734,659	602,826
South Germany and Thuringia	320,456	266,065	234,669
Saar District	1,370,980	954,738	801,597
Lorraine and Luxemburg	6,417,727	4,267,573	3,407,946
Total	19,309,172	14,389,547	11,789,931

At the close of the regular meeting of the German Steel Works Union on Dec. 7, 1916, the following statement on the condition of the German steel trade was issued: "In semi-finished steel demand has so increased that the most strenuous exertions are necessary to meet the urgent domestic requirements. Prices for the ensuing quarter are not changed. All contracts for neutral countries have been declined in the interest of domestic business. In railroad material the State Railways have placed their orders for heavy permanent way material for the next few months, the only requirements considered being those for war purposes. In shapes demand for army purposes is increasing, sales for the current quarter having been suspended. Orders from neutrals have been in most cases refused."[1]

Shipments of the German Steel Works Union continue to decline, having been only 212,675 metric tons in November, 1916, the lowest of any month since August, 1914, when they were only 96,984 tons. In October and September, 1916, they were 230,544 tons and 244,212 tons respectively. May was the high month in 1916, with 311,620 tons. The November shipments were made up of 67,880 tons of semi-finished steel, 82,099 tons of railroad material and 62,696 tons of shapes. Shipments in November, 1915, were 241,750 tons. Monthly deliveries were as follows:[2]

1916.	Semis.	Shapes.	Railway Material.	Total Tons.
January	75,045	53,394	157,345	285,784
February	74,491	66,702	141,076	282,269
March	82,787	74,865	153,994	311,646
April	83,132	68,688	119,936	271,756
May	80,765	88,528	142,327	311,620
June	77,483	86,685	134,585	298,753
July	69,386	83,024	130,465	282,875
August	73,208	82,646	94,977	250,831
September	79,935	78,735	85,548	244,213
October	76,384	72,723	81,447	230,554
November	67,880	62,696	82,099	212,675

A new high record for the war was made in the German steel output for October, 1916. The total was 1,423, 535 metric tons against 1,393,186 tons in September. The previous high record was 1,414,097 tons in August. The daily rate of production in October was 54,751 tons per day and in June 54,990 tons per day. The October output was made up of 684,003 tons of Bessemer ingots, 597,535 tons of open-hearth ingots, 117,871 tons of steel castings, 9947 tons of crucible steel and 14,279 tons of electric steel. The production of steel castings establishes a new record. The steel output in October, 1915, was 1,215,287 tons and in October, 1914, it was 900,201 tons. The output for 10 months to Nov. 1, 1916, was 13,354,418 tons against 10,892,378 tons to Nov. 1, 1915. The October rate is reported to have been 90 per cent. of that in the last months of peace.

[1] *Iron Age.*
[2] *Metal. Bull.*, Jan. 16, 1917.

PRODUCTION OF STEEL IN GERMANY
(In metric tons)

	1912(*a*).		1913.		1914.		1915.	
	Acid.	Basic.	Acid.	Basic.	Acid.	Basic.	Acid.	Basic.
Converter ingots...	187,179	9,794,300	155,138	10,629,697	100,617	8,269,600	....	....
Open-hearth ingots	295,256	6,871,896	380,155	7,592,901	361,564	6,518,874	....	....
Special steels......	153,367	....	200,928	....	184,432	184,432	....	....
Total (*b*).......	635,802	16,666,196	736,221	18,222,598	646,613	14,973,106	13,187,616	

(*a*) As reported by the German Iron & Steel Union. (*b*) Includes direct castings.

The extent to which the war has affected the prices of materials in the German iron and steel industry is indicated by the subjoined analysis, published by *Engineering*, London. Prices are marks per ton:

	Iron Ore.	Pig Iron, Middling Quality.	Billets.	Shapes.	Bar Iron.
Third quarter, 1914................	12.60	69.0	82.5	110	94– 97
Fourth quarter, 1914...............	12.80	74.0	90.0	110	94– 97
First quarter, 1915................	12.80	74.0	90.0	110	94– 97
Second quarter, 1915...............	14.20	81.0	97.5	120	135–140
Third quarter, 1915................	15.60	88.5	102.5	130	140–145
Fourth quarter, 1915...............	16.30	88.5	102.5	130	140–155
First quarter, 1916................	16.30	88.5	102.5	140	140–160
Second quarter, 1916...............	17.00	93.5	107.5	140	180–195

Raw material and unfinished steel rose more moderately than the finished materials. The most important advance in steel quotations took effect only after the end of the business year 1915–16. Despite this most of the companies showed brilliant balance sheets for the year. The sales of the German Steel Works Union amounted to only 3,200,000 tons out of an aggregate steel production of 14,750,000 tons.

Great Britain.—According to the returns of the Iron, Steel and Allied Trades Federation, the British production of pig iron last year was 9,047,983 tons against 8,793,659 tons in 1915. Of the total, hematite accounted for 4,042,014 tons against 3,564,276 tons in 1915, basic for 2,290,549 tons against 2,272,684 tons, foundry for 1,418,824 tons against 1,573,575 tons, and forge iron for 899,467 tons against 1,024,063 tons.[1]

Detailed statistics are given in the following table, classified according to kinds of iron:

	1913. Tons.	1914. Tons.	1915. Tons.	1916. Tons.
Forge and foundry...............	3,943,139	3,430,448	2,597,638	1,318,291
Bessemer and hematite...........	4,057,700	3,235,403	3,564,276	4,042,014
Basic...........................	2,125,689	2,003,693	2,272,684	2,290,549
Spiegel, ferro, etc.............	355,389	336,354	359,065	397,129
Total........................	10,481,917	9,005,898	8,793,659	9,047,983

[1] *Metal Bull.*, Apr. 13, 1917.

Production of pig iron for a number of years past has been as follows:

	Tons.		Tons.
1906	10,149,388	1912	8,889,124
1907	9,923,856	1913	10,481,917
1908	9,289,840	1914	9,005,898
1909	9,664,287	1915	8,793,659
1910	10,217,022	1916	9,047,983
1911	9,718,638		

The steel output was 9,244,457 tons against 8,550,015 tons. Bessemer acid steel totalled 1,196,153 tons against 821,408 tons in 1915; Bessemer basic 505,817 tons against 479,816 tons, open-hearth acid 4,393,004 tons against 4,090,752 tons, open-hearth basic 3,012,558 tons against 2,958,968 tons, electric ingots 30,968 tons against 20,000 tons, and electric castings 18,288 tons against 2000 tons.[1]

BRITISH STEEL OUTPUT BY GRADES

	Acid Bessemer.	Basic Bessemer.	Acid Open-hearth.	Basic Open-hearth.	Total.
1910	1,138,103	641,012	3,016,830	1,578,536	6,374,481
1911	887,767	573,373	3,131,118	1,869,354	6,461,612
1912	980,662	541,825	3,365,570	1,908,087	6,795,144
1913	1,048,772	551,929	3,811,382	2,251,793	7,663,876
1914	797,072	482,444	3,680,848	2,874,749	7,835,113
1915	821,408	479,816	4,090,752	2,958,968	8,550,015
1916	1,196,153	505,817	4,393,004	3,012,558	9,244,457

The production of puddled iron increased from 942,906 tons in 1915 to 951,107 tons in 1916.[2]

IRON AND STEEL EXPORTS, UNITED KINGDOM
(In tons of 2240 lb.)

	1910.	1911.	1912.(a)	1913.(a)	1914.	1915.	1916.
Pig iron	1,205,863	1,204,319	1,124,815	1,097,009	780,691	508,540	790,065
Wrought iron	141,747	138,089	142,461	137,335	90,405	....	....
Sheets	597,117	617,557	762,244	762,744	566,601	286,466	....
Plates	250,867	267,691	282,898	273,051	199,878	....	....
Rails	485,693	370,543	412,127	509,105	443,636	242,289	50,275
Steel shapes, etc.	369,020	347,828	361,992	368,498	300,653	489,464	617,159
Tin plates	483,020	484,355	480,910	495,246	435,497	368,000	....
All other kinds	1,208,578	1,088,727	1,211,102	1,295,453	1,071,546	1,252,540	....

The British Government's efforts to restrict iron and steel exports are meeting with success. The December exports, excluding iron ore and including scrap, were only 158,609 gross tons, the lowest for any month in 1916. The decline was regular in the last 4 or 5 months of the year, the high mark having been reached in May with 395,750 tons. The December exports were the lowest for any month in the last 3 years.

Taking 1916 as a whole the exports exceeded those for 1915 by only a little more than 100,000 tons—3,357,829 tons against 3,248,046 tons.

[1] *Loc. cit.*
[2] *Loc. cit.*

In 1913 they were about 5,000,000 tons, a year of exceptional export trade. The average value per ton of exports last year was £17 4s. as compared with £12 12s. in 1915 and £10 14s. in 1914.

The pig-iron exports in 1916 were exceedingly large, amounting to 790,065 tons, of which France took over 75 per cent. The average value per ton was £5 18s. as compared with £2 18s. 6d. in 1914 and £3 7s. 6d. in 1913. As to ferro-manganese, the statistics show that the United States was credited with 81,600 tons, or over 60 per cent. of the total exported, the remainder going almost entirely to the Allied countries. The average value per ton of exported ferro-alloys advanced rapidly, having been £21 15s. as against £8 10s. in 1914.

In rails the shrinkage in exports was decided, the total for 1916 having been only 50,275 tons, as compared with 242,267 tons in 1915. Steel bars showed a phenomenal increase, the total for 1916 having been 617,159 tons (France taking 519,888 tons) against 489,191 tons in 1915 and about 251,000 tons in 1913.

Imports of iron and steel, excluding iron ore and including scrap, in 1916, were only 872,890 tons as against 1,290,603 tons in 1915. The valuation, however, was considerably higher. Last year 6,905,936 tons of iron ore was imported or about 700,000 tons more than the imports of 1915, which is well up to the average of pre-war years. In 1913 the iron-ore imports were 7,442,000 tons. Imports of pig iron and finished iron and steel continue to decrease. Last year they were only 775,000 tons, the lowest figure for 16 years. In 1915 imports of American billets were 350,000 tons; in 1916 they were 120,000 tons.

Japan.[1]—Because the utter dependence on outside countries for its supplies of iron and steel materials has proved a serious drawback to Japan's industrial system, an Imperial ordinance was promulgated on May 7, 1916, providing for the organization of a council to be styled the Iron-Industry Investigation Commission. The commission is authorized not only to conduct investigations submitted by the Minister of Agriculture and Commerce but also to take the initiative when it is deemed necessary.

The fundamental problem before the commission will be to investigate the possible sources of ore supplies and devise plans for the acquisition of the ore thus discovered. Other important matters to be discussed are the question of the sorts of material the country most urgently requires and should try to produce before all others; the devising of measures for eradicating the clash of interests between Government-owned and private enterprises, and the means of accelerating the development of the iron industry in Japan.

[1] *Comm. Rept.*, June 12, 1916.

Netherlands.[1]—The Coöperatieve Inkoopvereeniging van Metaalindustrieelen (Coöperative Purchasing Society of Manufacturers of Metal Products) has just been organized in the Netherlands. It is composed of 38 large firms operating machinery factories, shipyards, and other establishments where iron and steel are necessary materials.

The special purpose of the society is to buy raw materials to better advantage than is now possible. The supplies of iron and steel used by the firms have come almost entirely from Germany and England, but lately the receipts from those countries have been far from sufficient. The firms naturally turn to the United States for relief.

New Zealand.[2]—A company has recently been formed in New Zealand, with a capital of £70,000 (about $340,000), with the object of producing iron and steel from magnetic and titaniferous iron sand, of which there is a large deposit on the coast at Taranaki, near New Plymouth, North Island. Works are being erected at New Plymouth. The present intention is to install a furnace capable of dealing with 70 tons of iron sand weekly, but plans have been drawn up for the installation at a later date of an additional furnace capable of dealing with 200 tons weekly. The company claims that pig iron can be produced from these iron sands at a cost not exceeding £3 ($14.60) a ton. The production of steel is also contemplated, and it is intended later to form a new company to carry out this development. Meanwhile the company will proceed with the production of pig iron for foundry purposes. Several attempts have been made to produce pig iron in commercial quantities, beginning as early as 1848. All were without success with the possible exception of the plant just completed which has turned out a few tons of excellent pig iron.

Norway.[3]—The Sydvaranger mines, at Kirkenes, in the extreme north of Norway, are now exporting about 500,000 tons of ore annually. The company is under Scandinavian control, but Germans have been taking great interest in affairs, through the agency of the Norddeutsche Bank of Hamburg.

Philippine Islands.—Iron ores are found chiefly in Luzon and Mindanao according to a recent paper by Wallace E. Pratt, of the Bureau of Science at Manila. It is now recognized that the iron-ore deposits in the eastern Cordilla of Luzon constitute, not a continuous belt, but a series of widely separated deposits, including a half dozen ore-bodies within a distance of 10 miles in Bulacan Province, a single outcrop at Santa Inez, Rizal Province, farther south, and three deposits around the margin of the Mambulao-Paracale gold-mining district in Camarines

[1] *Comm. Rept.*, Feb. 28, 1917.
[2] *Comm. Rept.*, Mar. 1, 1917.
[3] *L'Echo des Mines*, July 20, 1916.

Province, 100 miles farther to the east-southeast. Other unimportant occurrences of magnetite-hematite ores are known, but the foregoing, together with the lateritic ores in Surigao Province, Mindanao, contain the economically important iron ore reserves of the Philippines.

South Africa.—The small steel furnace at Vereeniging, Transvaal, is being replaced by a larger one, into the construction of which has entered locally-made magnesite and silica bricks, products which, it is stated, are destined to displace the imported articles. The furnace, of the latest open-hearth type, is supplied with a chrome-ore hearth from Rhodesian material. All castings for the furnaces are made on the spot, only the valves and chains being imported. Nothing but local bituminous coal is used to supply the gas required to melt the charges of steel. The latest type of Dibley valve is employed, and it is anticipated that the new furnace will turn out 1000 tons of steel a month, while the original small plant could produce only half that amount.

At present the Vereeniging foundry is working on "scrap," but it is claimed that within a few miles of the foundry lie deposits of high-class iron ore.[1]

Russia.—Pig-iron production in Russia for the first 6 months of 1916 is reported at 1,818,180 metric tons, against 1,887,385 tons and 2,365,108 tons for the first 6 months of 1915 and 1914 respectively. The production of finished iron and steel is returned as 1,621,620 tons to July 1, 1916, while to July 1, 1915, and 1914 respectively it was 1,644,240 tons and 2,147,106 tons. In 1916 to July 1, Russia imported 155,151 tons of finished steel, against only 24,226 tons to July 1, 1915.

A concession has been granted for the extraction of iron ore in the basin of the Yellow River, in the Bent Horn (Krivoi Rog) district near the station Zelionaya on the Kharkof-Nikolaief Railroad. The area of the land comprises over 16,000 acres. The concession is granted for 24 years on condition that $\frac{6}{10}$ kopeck is paid for every pood of ore extracted and shipped (about $0.17 per short ton), and that the holders of the concession must guarantee to extract enough ore to make the annual rent of the land amount to 6000 rubles ($3090). Rent will be charged from the time of beginning of actual extraction and shipment of the ore.[2]

The iron deposits in the basin of the River Telbess, right tributary of the River Kondoma, flowing into Tom River opposite the city of Kuznetsk, Siberia, have been known since the last century, but not until recently was the region surveyed. In 1913 it was turned over by Crown Land Administration to the Kuznetsk Coal Mine Joint-Stock Co., which undertook a careful study of the region with the view of establishing a large iron foundry and works.

[1] *Comm. Rept.*
[2] *Comm. Rept.*, July 11, 1916.

Over 10 independent iron deposits were discovered in the region. The main deposit is situated on the right bank of the Telbess River, some 5 miles from its influx into the Kondoma River; it is of an eruptive nature and consists mainly of granodiorite, quartz, porphyrites, and melaphyre, with secondary strata of crystalline limestone, hornblende, slate, etc. The normal sedimentary strata were discovered only to the north of the region, where the Telbess iron region is separated from the Kuznetsk coal region.

The volume of ore uncovered at the Telbess deposit proper amounts to 3,611,412 tons of 58 per cent. ore and 3,069,700 tons of poorer ore; and at the so-called Temir-Tau deposit to 7,222,824 tons of 54 per cent. ore and 1,305,706 tons of poorer ore. Studies of other deposits of the region in 1915 indicate that the total deposit amounts to 27,087,396 tons of ore.[1]

Spain.—The report of the commission appointed by the Spanish Government to study the iron and steel question in Spain has just been published in connection with a royal order based on facts disclosed by the investigating body.

It was found that although abundance of iron ore of excellent quality exists in Spain, iron manufacturers have been unable to develop business as they might, owing to the scarcity of coal and lack of facilities for proper treatment of the ore at the blast furnaces. The commission urges an increase in the quantity of ore smelted and a greater production of manufactured articles from the metal obtained instead of exporting ore and importing manufactured iron.

While present conditions continue, the export of the products of iron and steel plants shall be permitted only when the domestic demand is supplied. Neither dealers nor metallurgists may export metal except in form of manufactured goods produced in their factories or workshops, and then only in case local needs are covered.

The Ministry of Public Works will maintain experts to decide whether or not the domestic supply is sufficient and to examine petitions relating to this question. A board will be appointed to fix the maximum selling price of iron and steel, based on wages paid at different mines and on conditions peculiar to special localities. The prices to prevail during the succeeding month will be published monthly between the 20th and 25th.[2]

Careful estimates place the quantity of unmined iron ore in Spain at 700,000,000 tons, capable of yielding about 50 per cent. of metal. This vast mineral wealth is distributed throughout the various provinces, chief

[1] *Comm. Rept.*, July 6, 1916.
[2] *Comm. Rept.*, July 18, 1916.

among which are Leon with 150,000,000 tons; Teruel, 135,000,000 tons; Vizcaya, 70,000,000 tons; Lugo, 65,000,000 tons; Oviedo, 55,000,000 tons; Aragon, 40,000,000 tons; Seville, 35,000,000 tons; Santander, Malaga, and Almeria each possessing 25,000,000 tons.[1]

Nearly half of Spain's iron comes from the Province of Vizcaya, which yields beween 3,500,000 and 4,000,000 tons annually. Although this amount is relatively considerable, it is much less than the production of 15 years ago, when this Province astonished the industrial world by the richness of its iron mines, yielding then some 7,000,000 tons. This decrease in Vizcaya is offset by the development of iron mining in the Provinces of Santander, Lugo, Teruel, and others where iron has been found. Fortunately the loss has not only been compensated but the total production has been augmented.[2]

Iron-ore exports from Spain in 1916 were larger than in 1915, despite shipping conditions. The 1916 shipments were 5,148,127 metric tons, against 4,509,214 tons in 1915 and 6,095,121 tons in 1914. Shipments of iron pyrites were 2,743,487 metric tons in 1916, 2,268,223 tons in 1915 and 2,553,798 tons in 1914. It is stated that phosphoric iron ores, which before the war went largely to Germany, have been bought in larger amounts by England and France, particularly England. Such mines which closed down after the war started have resumed operations.

Sweden.—Official returns of the Swedish iron and steel industry, according to *Iron Age*, Feb. 22, 1917, give the pig-iron output in 1915 at 760,701 metric tons. Of the total, 419,686 tons was open-hearth iron, 161,835 tons forge iron, 121,476 tons Bessemer iron and 45,931 tons foundry iron. Furnaces in blast were 120, with an average output of 21.4 tons per day. Charcoal was almost exclusively the fuel, 674,360 tons having been used.

The output of pig iron and steel from electric furnaces in 1915 is given as follows in recent official data:

	Metric Tons.
Pig iron	35,075
Silicon steel	11,819
Silico-manganese steel	2,328
Manganese steel	947
Chrome steel	242
Silico-manganese-aluminium steel	785
Silico-aluminium steel	346
Vanadium steel	4

At the beginning of 1914, there were five electric furnaces producing pig iron, with three more in contemplation. Each had a power of 2000 to 3000 kw. In 1915 there were 10 electric furnaces producing steel.

The output of wrought-iron blooms was 119,629 tons; Bessemer-steel ingots, 91,070 tons; open-hearth steel, 503,766 tons; crucible steel,

[1] *Comm. Rept.*, Oct. 26, 1916.
[2] *Comm. Rept.*, July 7, 1916.

3395 tons; electric steel, 2187 tons, and blister steel, 148 tons. The forged iron and steel production was 42,403 tons and the rolled iron and steel 830,167 tons.

Ore output included 7607 tons of manganese ore, 55,937 tons of zinc ore, 1642 tons of nickel ore and 76,324 tons of pyrites.

Technical Advances in Iron and Steel[1]

By J. E. Johnson, Jr.

The iron and steel business has enjoyed, during the past year, prosperity that has made its palmiest days in time gone by look almost like poverty, and it is equally true that there have been in 1916 no important technical advances in the industry, no long strides to distinguish the year. These two facts stand to one another in the relation of cause and effect.

The organization of the steel works is limited. In bad times it is cut to the bone. When unexampled prosperity succeeds unprecedented dullness almost over night, as was the case a little more than a year ago, idle plants start up and to do so draw their organization in part from those still running, but short-handed. This tends to reduce the staff at the time when the drafts upon it are the greatest, for the commercial demands of the business are such that output must be obtained at whatever sacrifice of other considerations. When outputs of 100 to 110 or 120 per cent. are demanded of a plant, it means that the organization must be strained almost to the breaking point before it can be built up to meet the conditions. The energy of the staff, which in normal or dull times would expend itself in methods for cheapening production or improving product, must all be devoted to output, since improvements, perhaps even those already contemplated, must be laid aside unless they are of a nature to make immediate return in the form of increased output. For these reasons, all the technical advances made this year have been of the slow, evolutionary order which comes from merely taking short forward steps in directions previously shown to be advantageous.

The By-product Coke Oven.—The past year has seen the fruition of two developments in the line of fuel which have been under way for a long time —one, the final success of the by-product oven; the other, of powdered coal as a metallurgical fuel.

The technical superiority of the by-product oven over the bee-hive was admitted by the well-informed 2 or 3 years ago, but the enormous war prices for benzol and toluol obtained from its gases were required to bring about its rapid introduction. These compounds are at the basis

[1] *Iron Age*, Jan. 4, 1917.

of the aniline dye industry, and are the raw materials for picric acid and trinitrotoluol, the explosives used in high-explosive shells. It is, of course, the demand from this latter source which has given the remarkable values to these compounds during the last year and a half; but with the development of the dye industry already promised it may be doubted whether these products will ever decline to their insignificant position before the war and the price they then commanded.

These compounds are present in the gases from the coke oven in the form of vapor and are recovered therefrom by scrubbing the gas with an oil which has a high absorbing power for them. This oil may be one derived either from tar or from a petroleum with a paraffin base. The scrubbing oil containing the benzol and toluol is treated in a vertical continuous still, much like an alcohol still, in which these comparatively volatile by-products are driven off as vapors and condensed in a surface condenser, while the scrubbing oil, properly cooled, is returned to the scrubbing towers.

The by-products derivable from coke-oven tar are almost innumerable, and some of these are being recovered, which in this country never were before, on account of the scarcity brought about by the war. This has contributed its quota to the earnings of the by-product coke plant, though the value is insignificant in comparison with that of benzol.

Iron Ore.—In the iron-ore field nothing strikingly new has been done, although there has been steady development in the lines of magnetic separation, of washing the sandy ores of the western Mesabi and of sintering. The iron and steel industry is just beginning to realize that merchantable ore of high grade may be concentrated from unusable rock, and that the cost of treating some ores outside the furnace may be less than that of putting them through untreated. This is destined to affect the whole industry profoundly within the next few years.

The Blast Furnace.—The blast furnace has had its principal development along the lines of better stock distribution, better hot-blast stoves and more economical power plants.

Fifteen years ago many furnacemen were satisfied with almost any distribution they happened to get from the apparatus installed, but this most important operation of the whole blast-furnace industry can not be ignored without causing low output and high coke consumption. The remarkably low fuel consumption authenticated in some instances has been a gage of the inefficiency of some other plants, and the subject of stock distribution is receiving a degree of consideration to which it has been a stranger for 15 or 20 years. The one strikingly new thing in this field is the introduction of the Slick saw-tooth distributer under the main bell, which gives the charge column a columnar structure with alternate columns of coarse and fine instead of the uniform layers produced by most systems of filling. Highly beneficial results are claimed for this improvement, and the writer has had experience which leads him to believe that these claims are correct.

Nothing radically new is being done in the field of furnace boilers, but all the conditions affecting combustion are being carefully studied and boiler efficiencies are being marked up from the common 55 per cent. of the present and recent past to 70 or 72 per cent. This is a matter of better burners, better setting and better regulation of the air and gas supply and of the intensity of the draft, rather than strikingly new or great steps in this field. This increased efficiency of boilers is cutting down the technical lead of the gas engine, and, with a great economy possible with large turbine units, has about eliminated the gas engine from the competition for power purposes where coal is cheap, especially when the fixed charges and operating costs as well as the fuel costs of the two types of apparatus are considered.

In stoves, the tendency has continued toward increasing the quantity of brick and increasing the surface exposed by reducing the thickness of the checker walls and the size of the checker openings. One stove has been put into service which will heat 50,000 cu. ft. of wind to 1300° for 2 hr. with only 2 hr. on gas. Theoretically two such stoves would be enough for a furnace. Practically a third will always be added by the wise operator to prevent complete interruption to operation when one comes off for temporary repairs. This is a four-pass stove and the thickness of the checker bricks in the last pass is only 1½ in. The weight of fire-brick and the surface exposed are enormous. Of course, this stove would be worthless in a week on dirty gas, and the use of such stoves must necessarily involve an absolutely reliable gas-cleaning system. If stoves of this capacity shall prove durable in service, it means that the five stoves, which in recent years have been considered good practice at plants smelting refractory ores, will become obsolete, and will give way at new plants to the three stoves with which we started 30 or 40 years ago.

Potash Recovery.—One of the interesting developments of the year has been the commercial recovery of potash from flue dust. R. J. Wysor, of the Bethlehem Steel Co., has conducted a very extensive research in connection with this matter and has proved that the percentage of potash entering the blast-furnace charge is much more considerable than has generally been believed.

At several plants the fine dust which deposits in the base of the stoves has been collected and sold for good prices for its potash-content. Where the gas is cleaned by the wet process, a very large percentage of the potash is dissolved and passes off in the cleaning water. This furnishes an additional argument for the discovery of some system for dry cleaning gases. Mr. Wysor has found that when potash is present in considerable quantities and not thoroughly removed from the gas, it has a destructive effect upon the brickwork of the stoves. This constitutes an additional argument for the complete recovery and commercial utilization of this valuable material. We may expect to see steady if not spectacular progress in this direction for several years to come.

Steel Production.—The year saw rapid strides in the introduction of pulverized fuel in the open-hearth furnace.

Powdered coal is being used exclusively for open-hearth and heating furnaces in one steel plant, and is being tried out in various others. The detail steps necessary to produce this fuel successfully are now understood, and enough is known about its combustion to permit its use, though those best informed are most inclined to doubt whether they have achieved the perfect method of combustion.

In open-hearth furnaces the coal is blown into the outer end of the port by a jet of air under relatively high pressure, and is surrounded by a jet of compressed air which carries it into the current of heated air coming up through the regenerator. Special precautions are taken in the construction of slag and ash pockets over the regenerators to prevent their being filled by the fine ash from the coal. The large amount of radiant heat obtained from the direct combustion of the carbon particles in the furnace is found to be a decided advantage. On the economic side it may be roughly stated that it costs less to pulverize than to gasify a ton of coal, and that the gas contains only 80 per cent. of the energy of the coal after it is produced, while the powdered fuel contains it all.

This development is regarded as a technical and commercial success at least in some plants, and the importance of the gas producer in the steel works appears likely to sustain a hard blow.

Investigations of the open-hearth furnace in recent years have shown that its thermal efficiency is exceedingly low. The checkerwork can not be built large enough to extract anything like all the heat from the waste gases, and in order to prevent the complete loss of this, the practice was started 2 or 3 years ago of introducing waste-heat boilers into the system, placing them between the regenerators and the stack. It was well known, of course, that some power could be obtained in this way, but it was by no means certain the commercial value of this power would exceed the fixed charges on the installation. This fact has now been positively ascertained and the use of waste-heat boilers in conjunction with open-hearth furnaces seems likely to grow. This, of course, is a return to the practice standard in puddling mills a generation or more ago, when a large quantity of the steam required was developed in boilers erected over the puddling furnaces.

The duplex process has made decided gains and it seems probable that within a few years most of the steel made in the large works will be produced with this process. The Bessemer will undoubtedly continue to be used for pipe and certain other purposes, such as bolt stock, for an indefinite period. The open-hearth will also continue to be used indefinitely at plants too small to consume the output of a duplex installation, but in the rest of the steel-producing field the preponderance of the duplex process seems likely to increase.

The record of the Patent Office indicates that at the largest steel plant which uses high-phosphorus iron progress has been made in the last year or two in the concentration of the phosphorus in a portion of the open-hearth slag, so as to practically equal that in basic Bessemer slag, thereby recovering a valuable by-product.

Ingot Casting.—The question of casting ingots is receiving constantly more and more attention. The extreme severity of the specifications for shell rounds, of which millions of tons have been made for the European nations in the past year and a half, has been partly responsible for this. The yield of merchantable steel in some plants has been less than 50 per cent. of the weight of the ingots, with little or no disposition available for the remaining 50 per cent. except re-melting. This has put a decided premium on methods of casting which could reduce the losses from piping, segregation, etc.

It is claimed by some that the shorter pipe in the ingot cast big end up is more than offset by the fact that the cross-section of the ingot is larger, and that the gross volume required to be cropped is larger than that of ingots cast in the standard way. This seems contrary to the best theory of the subject, and rapid progress is to be expected in casting ingots big end up. Other methods eliminating or reducing the pipe in the ingot are receiving serious consideration.

No advances in steel rolling have been made in the past year, except the minor steps incident to normal growth. The electrically driven reversing blooming mill is making rapid strides in spite of the high fixed charges involved in its introduction.

The Automobile as a Consumer.—The automobile has made itself increasingly felt as a consumer of iron and steel. One steel works in the Central West, which has made a specialty of alloy steels for the automobile trade, has been swamped with orders in spite of great increases in capacity. A large part of its tonnage is special alloy steels, such as chrome-vanadium, chrome-nickel and the like. The largest producer of automobiles has let contracts for the construction of two blast furnaces whose output will go directly into finished castings by a process not yet disclosed. These will be used for automobiles and gas tractors.

Centrifugal Castings.—Outside the process just referred to, of making castings direct from the blast furnace, there has been nothing strikingly new in the production of castings, although for a year or two an active interest has been taken in making hollow cylindrical castings in rotating molds. Very remarkable castings in steel, iron and bronze have been made in this way. The centrifugal force developed by the high rotative speed of the mould tends to densify the metal and at the same time gives a chance for the evolution of the gas which it contains. It is as if the effects of gravity in throwing off gases were multiplied many fold.

In recent months it is understood that a process of casting in this way has been developed with particular reference to short sections of cast-iron pipe, like sewer pipe, and that an improvement has been added to the process whereby the castings are removed from the mould as soon as they are set, so that very great outputs can be obtained from a given machine. Full details are not at hand, but the process seems to promise well.

The Electric Furnace.—One of the important developments of the past year has been the increase in the use of electric furnaces. These are in practically no case for the production of iron or steel, but merely for melting or refining iron and steel already produced. The quality of material which can be produced in this way is undoubtedly superior to that which can be produced in the open-hearth furnace, and is probably equal to the best that the crucible can do, because the electric furnace is simply a large crucible, not requiring the presence of any gases of combustion for heating as the open-hearth does. It could even be worked *in vacuo,* if that were necessary. Triplexing, which generally means the refining of steel made by the Bessemer and basic open-hearth in the electric furnace, is increasing for special qualities of material.

For high-grade materials, where quality is of paramount importance, the electric furnace seems to have a field all its own, and owing to the fact that under special conditions current for it can be bought from public service companies during "off-peak" periods, its installation cost is not necessarily high. This permits its use in plants smaller than otherwise would be justified in making their own steel.

Steel Rails.—The steel rail had a position of secondary importance commercially during the past year, because the economic pressure under which the railroads have been laboring for several years, exerted by the commissions on one side and the labor unions on the other, has almost completely prevented the construction of new lines. At the same time the growth in the use of steel for other purposes has been enormous, and these two factors have reduced the steel rail from its once dominant position to a subordinate one. Nevertheless, the subject continues to excite the liveliest interest.

In the form of rails steel receives the hardest service to which it is subjected. About 40 years ago the railroads used 10-ton cars with a gross weight of 16 or 18 tons, and 56-lb. rails; today they are using almost exclusively 50- and 70-ton cars with gross weights of 72 and 100 tons, while the first of the 120-lb. rails are now beginning to appear. In other words, in 40 years the load on the rails has increased four to six times, and the weight of the rail has barely doubled; on the average it has not nearly done so.

The railroads continue to express their disapproval of the steel men because the latter can not guarantee their product absolutely against failure under these conditions. The transverse fissure continues to constitute a terrible menace to the railroads, since the section of the head may be reduced to a fraction of its safe area at one of these fissures without the latter ever appearing on the surface until its failure under load occurs, and a train wreck results. This is a comparatively new defect, or at least its importance in the total of rail defects has grown enormously in the last few years. The experts of the railroads are trying to attribute it to bad mill practice, but no adequate proof of this contention has as yet been adduced. On the other hand, the probability that these failures are caused by plastic flow of the steel in the surface of the head, due to the tremendous local loads put upon them by the wheels, does not appear to have been sufficiently investigated.

Tool Steels and Ferro-alloys.—One of the interesting features of the steel business in the past year has been the spectacular advance in price of tool steels and the alloy metals used for producing high-speed steel. No startling technical developments have so far resulted from the astonishing prices which these materials have commanded, but uranium steel gives a promise which, if confirmed, will have a profound influence on the whole high-speed steel situation. The use of vanadium has experienced a healthy growth. In the days of early development too much was claimed for it in some cases, and the reflex of this was injurious, but it has now been demonstrated beyond a possibility of doubt that vanadium imparts elastic and shock-resisting qualities which can not be obtained with any other element so far discovered.

LEAD

By C. H. Bender

The lead industry in 1916 made good gains in output, both in mining and smelting. The lead content of ore mined in the United States in 1916 was about 622,000 short tons, compared with 561,639 tons in 1915, an increase of 60,000 tons, or over 10 per cent. The average price of lead in 1916 was so much higher than in 1915 that the increase in value of the mine output of lead was about 50 per cent.

The Northport Smelting & Refining Co. in March blew in the remodeled smelter at Northport, Wash., and later in the year added two more lead furnaces, making four in all. The operation of the smelter gave an impetus to the production of lead in Washington, the output of which was four times as large as ever before. The Bunker Hill & Sullivan smelter was started at Kellogg, Idaho, and is expected to be in operation in the spring of 1917.

The State that recorded the largest gain in lead production was Missouri, which made an increase of over 25,000 tons. Good gains were also made by California, Idaho, Nevada, Utah, and New Mexico.

The following statistics have been compiled by C. E. Siebenthal from reports made to the United States Geological Survey, Department of the Interior, by all the lead refineries and soft-lead smelters in operation during the year. The statistics of imports, exports, and lead remaining in warehouse have been taken from the records of the Bureau of Foreign and Domestic Commerce.

The production of refined lead, desilverized and soft, from domestic and foreign ores in 1916 was 571,134 tons, worth at the average New York price $78,816,000, compared with 550,055 tons, worth $51,705,000, in 1915, and with 542,122 tons, worth $42,286,000, in 1914. The figures for 1916 do not include an output of 24,038 tons of antimonial lead, compared with 23,224 tons in 1915 and with 16,667 tons in 1914. Of the total production, desilverized lead of domestic origin, exclusive of desilverized soft lead, was 316,469 tons, against 301,564 tons in 1915 and 311,069 tons in 1914; and desilverized lead of foreign origin 18,906 tons, compared with 43,029 tons in 1915 and 29,328 tons in 1914. The production of soft lead, mainly from Mississippi Valley ores, was 235,759 tons, compared with 205,462 tons in 1915 and 201,725 tons in 1914. The total production of desilverized and soft lead from domestic ores was thus 552,228 tons, compared with 507,026 tons, in 1915, a gain of 45,202 tons.

METALLURGICAL PRODUCTION OF LEAD IN THE UNITED STATES[1] (a)
(Refinery statistics. In tons of 2000 lb.)

Year.	Domestic Origin.					Foreign Origin.		Grand Total.
	Desilverized.	Antimonial.	S. E. Mo.	S. W. Mo.	Total.	Desilverized.	Antimonial.	
1911........	211,041	8,916	155,008	25,993	400,958	89,487	4,929	495,374
1912........	236,207	9,239	145,366	19,224	410,036	82,715	5,003	497,754
1913........	261,616	16,345	133,203	22,312	433,476	54,774	2,300	490,550
1914........	318,697	17,177	177,413	25,448	538,735	28,475	1,119	568,329
1915........	305,160	24,601	185,849	20,312	535,922	43,301	2,883	582,106
1916........	327,905	19,044	205,802	30,747	583,498	20,152	2,978	606,628

(a) From *Eng. Min. Jour.*

Imports and Exports

The imports of lead were 17,543 short tons of lead in ore, 12,131 tons of lead in base bullion, and 5656 tons of refined and old lead, a total of 35,330 tons, valued at $3,468,000, compared with 51,496 tons in 1915. Of the imports in 1916 about 24,198 tons came from Mexico, against 47,124 tons in 1915.

The exports of lead of foreign origin smelted or refined in the United States showed a great decrease. They were 9880 tons, worth $1,111,653 against 38,618 tons in 1915 and 21,545 tons in 1914. This does not include foreign lead manufactures exported with benefit of drawback, which amounted to 5171 tons. For the last 3 years notable quantities of domestic lead have been exported to Europe, and the total for 1916 was 100,565 short tons, valued at $13,508,203, compared with 88,306 tons, valued at $7,928,518 in 1915.

IMPORTS OF LEAD, IN ORE, BASE BULLION, AND REFINED, BY COUNTRIES, IN POUNDS

Country.	1910.	1911.	1912.	1913.	1914.	1915.	1916.
United Kingdom	1,874,750	401,686	279,546	404,594	245,548	185,236	261,406
Germany.........	421,377	56,286	494,237	262,132	4,529,919	....	....
Other European countries.	418,669	111,189	55,356	143,293	123,085	32,537	314,353
British North America.	206,979	270,947	319,497	338.569	384,007	2,303,170	12,606,216
Mexico.	203,290,307	172,633,479	159,455,664	95,693,439	46,282,207	94,247,384	48,395,670
South America...	6,598,263	4,778,221	3,207,936	8,766,327	2,417,744	5,420,567	6,235,758
Other countries..	4,394,421	1,651,544	3,309,365	8,685,612	2,694,293	802,516	2,845,949
Total imports.	217,204,766	179,903,352	167,121,601	114,293,966	56,676,803	102,991,410	70,659,352

[1] These figures include the lead derived from scrap and junk by primary smelters.

IMPORTS OF LEAD, BY CLASSES, IN POUNDS

Year.	Lead in Ore (Lead Content).	Base Bullion.		Pigs, Bars, Sheets, and Old.	Total Lead Content.
		Gross Weight.	Lead Content.		
1909	71,357,868	149,852,559	146,579,779	7,152,665	225,090,312
1910	94,751,054	118,061,415	115,483,542	6,970,170	217,204,766
1911	35,686,180	141,481,852	138,952,372	5,264,800	179,903,352
1912	19,577,499	152,420,624	146,999,168	544,925	167,121,592
1913	19,883,313	96,908,170	94,327,654	82,999	114,293,966
1914	23,649,637	33,444,503	32,730,320	296,846	56,676,803
1915	18,185,140	86,247,995	83,986,988	819,282	102,991,410
1916	35,086,100	24,943,660	24,262,435	11,310,817	70,659,352

PIG LEAD EXPORTED FROM THE UNITED STATES (Short tons)

Destination.	1914.		1915.		1916.	
	Domestic.	Foreign.	Domestic.	Foreign.	Domestic.	Foreign.
Canada	4,082	28	20,089	4,275	37,095	983
Great Britain	24,158	10,233	31,192	20,031	8,048	2,277
Netherlands	6,739	1,620	945	2,507	2,553	611
Belgium	2,661	746	....	....	....	....
France	....	560	9,272	2,515	673	174
Italy	589	71	2,009	2,591	336	....
Germany	7,382	1,681	....	....	....	....
Russia	6,711	5,717	13,524	3,869	17,960	1,285
Japan	2,247	....	3,420	560	14,879	1,765
Other countries	4,163	889	7,855	2,270	19,021	2,785
	58,722	21,545	88,306	38,618	100,565	9,880

Lead Available for Consumption

The amount of lead available for consumption during 1916 may be estimated by adding to the stock of foreign lead (domestic stocks are

PRIMARY REFINED LEAD AVAILABLE FOR CONSUMPTION IN THE UNITED STATES[1]
(Short tons)

	1911.	1912.	1913.	1914.	1915.	1916.
Supply:						
Stock in bonded warehouses Jan. 1	35,972	4,481	10,492	5,310	7,668	12,169
Imports—						
For consumption	13,281	14,146	11,980	7,386	9,680	12,771
For warehouse	76,671	69,414	45,165	20,952	41,816	22,559
Increase by liquidation	....	....	....	....	2,250	5,642
Production from domestic ores	391,995	392,517	411,878	512,794	507,026	552,228
Total supply	517,919	480,558	479,515	546,442	568,440	605,369
Withdrawn:						
Exports of foreign lead—						
From warehouse	101,227	64,906	44,544	21,545	38,618	9,880
In manufactures, with benefit of drawback	12,080	11,320	9,757	9,399	3,983	5,171
Exports of domestic lead	....	....	....	58,722	87,306	100,565
Decrease by liquidation	14,812	5,692	419	56	....	....
Stock in bonded warehouses Dec. 31	4,481	10,492	5,310	7,668	12,169	12,369
Total withdrawn	132,600	92,410	60,030	97,390	142,076	127,985
Available for consumption	385,319	388,148	419,485	449,052	426,364	477,384

[1] U. S. Geol. Surv.

not known) in bonded warehouses at the beginning of the year (12,169 short tons) the imports (35,330 tons), the additions by liquidation (5642 tons), and the domestic production (552,228 tons), making an apparent supply of 605,369 tons. From this are to be subtracted the exports of domestic lead (100,565 tons), the exports of foreign lead (9880 tons), the foreign lead contained in articles exported with benefit of drawback (5171 tons), and the stock in bonded warehouses at the end of the year (12,369 tons), leaving as available for consumption 477,384 tons, compared with 426,364 tons in 1915.

The Lead Market in 1916

Lead began the year at New York with a price of 5.5 cts. per lb., the minimum price of the year, and rose to 8 cts., early in April, this being the maximum figure. A long decline carried the price down to 5.95 cts. per lb. in the early part of August. Another rise reached 7 cts. about the middle of September, after which the price remained stationary until early in December, when it advanced to 7.5 cts., and it closed the year at about that figure. The average New York price for the year was 6.8 cts., compared with 4.7 cts. in 1915, 3.9 cts. in 1914, and 4.4 cts. in 1913.

AVERAGE MONTHLY PRICE OF LEAD PER POUND IN NEW YORK(a)

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
	Cts.	*Cts.*	*Cts.*	*Cts.*	*Cts.*	*Cts.*	*Cts.*	*Cts.*	*Cts.*	*Cts.*	*Cts.*	*Cts.*	*Cts.*
1902...	4.00	4.075	4.075	4.075	4.075	4.075	4.075	4.075	4.075	4.075	4.075	4.075	4.069
1903...	4.075	4.075	4.442	4.567	4.325	4.210	4.075	4.075	4.243	4.375	4.218	4.162	4.237
1904...	4.347	4.375	4.475	4.475	4.423	4.196	4.192	4.111	4.200	4.200	4.200	4.600	4.309
1905...	4.552	4.450	4.470	4.500	4.500	4.500	4.524	4.665	4.850	4.850	5.200	5.422	4.707
1906...	5.600	5.464	5.350	5.404	5.685	5.750	5.750	5.750	5.750	5.750	5.750	5.900	5.657
1907...	6.000	6.000	6.000	6.000	6.000	5.760	5.288	5.250	4.813	4.750	4.376	3.658	5.325
1908...	3.691	3.725	3.838	3.993	4.253	4.466	4.477	4.580	4.515	4.351	4.330	4.213	4.200
1909...	4.175	4.018	3.986	4.168	4.287	4.350	4.321	4.363	4.342	4.341	4.370	4.560	4.273
1910(a	4.700	4.613	4.459	4.376	4.315	4.343	4.404	4.400	4.400	4.400	4.442	4.500	4.446
1911(a	4.483	4.440	4.394	4.412	4.373	4.435	4.499	4.500	4.485	4.265	4.298	4.450	4.420
1912(a	4.435	4.026	4.073	4.200	4.194	4.392	4.720	4.569	5.048	5.071	4.615	4.303	4.471
1913(a	4.321	4.325	4.327	4.381	4.342	4.325	4.353	4.624	4.698	4.402	4.293	4.047	4.370
1914(a	4.111	4.048	3.970	3.810	3.900	3.900	3.891	3.875	3.828	3.528	3.683	3.800	3.862
1915(a	3.729	3.827	4.053	4.221	4.274	5.932	5.659	4.656	4.610	4.600	5.155	5.355	4.628
1916(a	5.921	6.246	7.136	7.630	7.463	6.936	6.352	6.244	6.810	7.000	7.042	7.513	6.858

(a) From *Eng. Min. Jour.*

The London price of lead was higher than the New York price for the first quarter, but below it for almost the whole of the last three quarters of the year. The London price started the year at £30 7s. 6d. a long ton (6.57 cts. per lb.) and rose to £36 7s. 6d. a ton (7.87 cts. per lb.) in the latter part of March. Paralleling the New York market, a long decline brought the price down to £28 a ton (6.06 cts. per lb.) in July, at which it remained through the month. A sharp rise followed by a decline and another rise brought the price up to £31 10s. a ton (6.82 cts. per lb.) late in September. A decline to £30 10s. a ton (6.6 cts. per lb.) took place early in October, after which the price remained practically stationary. The average price of lead at London during 1916 was about £31 1s. 7/10d. a long ton (6.7 cts. per lb.).

AVERAGE MONTHLY PRICE OF LEAD PER 2240 LB. AT LONDON (a)
(In pounds sterling)

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
1902....	10.567	11.617	11.508	11.596	11.600	11.271	11.233	11.121	10.892	10.746	10.717	10.754	11.262
1903....	11.304	11.708	13.225	12.404	11.800	11.437	11.383	11.146	11.167	11.108	11.108	11.179	11.579
1904....	11.558	11.592	12.037	12.254	11.754	11.521	11.667	11.737	11.787	12.187	12.892	12.775	11.983
1905....	12.875	12.462	12.296	12.658	12.762	13.000	13.608	13.958	13.950	14.679	15.337	17.050	13.719
1906....	16.850	16.031	15.922	15.959	16.725	16.813	16.525	17.109	18.266	19.350	19.281	19.609	17.370
1907....	19.828	19.531	19.703	19.975	19.688	20.188	20.350	19.063	19.775	18.531	17.281	14.500	19.034
1908....	14.469	14.250	13.975	13.469	12.938	12.600	13.000	13.375	13.125	13.375	13.538	13.156	13.439
1909....	13.113	13.313	13.438	13.297	13.225	13.031	12.563	12.475	12.781	13.175	13.047	13.125	13.042
1910....	13.650	13.328	13.063	12.641	12.550	12.688	12.531	12.513	12.582	13.091	13.217	13.197	12.920
1911....	13.009	13.043	13.122	12.889	12.984	13.260	13.530	14.260	14.744	15.332	15.821	15.648	13.970
1912....	15.597	15.738	15.997	16.331	16.509	17.588	18.544	19.655	22.292	20.630	18.193	18.069	17.929
1913....	17.114	16.550	15.977	17.597	18.923	20.226	20.038	20.406	20.648	20.302	19.934	17.798	18.743
1914....	19.665	19.606	19.651	18.225	18.503	19.411	19.051	(b)	(b)	(b)	18.500	19.097	.....
1915....	18.606	19.122	21.883	21.094	20.347	25.170	24.611	21.946	23.151	23.994	26.278	28.807	22.917
1916....	31.167	31.988	34.440	34.368	32.967	31.011	28.137	29.734	30.786	30.716	30.500	30.500	31.359

(a) The statistics for 1902–1905 are from the report of the Metallgesellschaft, Frankfurt-am-Main. Those for subsequent years are from the *Eng. Min. Jour.* (b) London exchange closed.

At the beginning of March lead was actually quoted higher in St. Louis than in New York. This resulted from the ability to ship lead for export westward and southward from St. Louis, ocean freight being easier in those directions than from Atlantic ports. Throughout March lead was the sensational feature of the metal markets. The A. S. & R. Co. made advances in price, but independent producers were immediately able to get more. When the A. S. & R. Co. reached 7 cts., it stopped, while the outside market kept on to 8 cts.

White Lead and Oxides[1]

The prices of metallic lead and all its pigments broke all records of 50 years or more during 1916, and the effect has undoubtedly been to somewhat curtail consumption, especially of white lead. This result was, however, traceable in part to the backward spring and unfavorable weather for painting during the first four months of the year. The short-lived advance in prices in the summer of 1915 naturally made all classes of buyers skeptical as to the permanence of the rapid upward movement during the closing months of that year and the first quarter of 1916, and they generally restricted purchases to actual current requirements. When the trade, as well as consumers, realized that lead, in common with other metals, had established a higher normal basis which was likely to be maintained so long as the European war lasted, buying was resumed

[1] *Eng. Min. Jour.*

with more confidence, although the effect on consumption has been more or less in evidence throughout the year, and in spite of increased business during the summer and early fall months, the year's aggregate tonnage will be somewhat below 1915.

The pigments followed the course of pig lead during the first 3 months and in March reached record figures from which there was practically no recession following the decline on the metal, for the reason that manufacturers foresaw a subsequent advance on the latter and were desirous of avoiding the unsettling influences of frequent changes in the prices of their own products.

During the midsummer months the differential between pig lead and its pigments was so wide as to lead consumers of the latter to look for lower prices, and this had the effect of making them conservative buyers, but apparently did not check consumption, which was exceptionally good. With the higher prices for the metal that became effective during August, confidence in the stability of prices on all lead products became more fully established.

Dry white lead, which opened at a minimum of 6¼ cts., advanced steadily up to March 17, when it was fixed at 8¾ cts., where it has since remained, with a liberal consumption, due in part to the higher cost of some of the competing pigments. White lead in oil, which opened at 7¼ cts., began its upward course early in January and in March reached 9¾ cts., the highest price in more than 50 years. This price has remained the established quotation since that date, but with concessions on the part of some of the smaller manufacturers induced by the lower cost of metal during the summer months.

PRODUCTION OF LEAD PIGMENTS IN THE UNITED STATES

Year.	Red Lead.		White Lead. (a)		Litharge.		Orange Mineral.	
	Short Tons.	Value.	Short Tons.	Value.	Short Tons.	Value.	Short Tons.	Value.
1900...	10,098	$1,050,192	96,408	$9,910,742	10,462	$1,067,124	825	$100,650
1901...	13,103	1,448,550	100,787	11,252,653	9,460	979,586	1,087	224,667
1902...	11,669	1,262,712	114,658	11,978,172	12,755	1,299,443	867	138,349
1903...	12,300	1,385,900	112,700	12,228,024	12,400	1,326,800	1,000	168,000
1904...	13,938	1,672,569	126,336	13,896,913	12,487	1,248,691	1,125	168,681
1905...	16,269	1,919,767	122,398	12,068,443	12,643	1,422,616	1,000	120,000
1906...	13,693	1,874,448	123,640	15,234,990	13,816	1,890,050	2,927	421,488
1907...	13,370	1,778,717	111,409	12,254,297	14,769	1,624,553	815	123,917
1908...	11,358	1,156,282	116,628	10,515,315	12,254	1,231,206	393	43,157
1909...	15,800	1,438,197	131,643	12,652,638	13,391	1,266,903	530	68,003
1910 (b)	16,116	1,482,672	134,276	13,024,762	13,659	1,283,940	541	70,335
1911 (b)	19,594	2,345,520	132,612	17,393,241	25,190	2,733,196	766	119,370
1912 (b)	21,120	2,571,702	146,833	18,683,461	29,111	3,194,194	545	88,240
1913 (b)	17,635	2,127,976	142,626	18,112,219	23,093	2,524,707	434	71,625
1914 (b)	18.697	2,151,054	159,474	19,943,239	27,345	2,856,092	426	70,019
1915 (b)	19,435	2,397,900	156,101	19,393,691	26,118	2,822,415	....	....

(a) The output of "sublimed white lead," a mixed sulphate and oxide of lead, is not included in 1904-1910. (b) U. S. Geol. Surv.

Linseed oil has been abnormally high, having reached the record figure of $1 per gal. in November, and this has so far increased the cost of lead in oil to the manufacturer as to check much of the tendency to offer low competitive prices. It has also increased the cost of paint to such an extent as to help check the consumption of that commodity during the last month.

Lead oxides have followed the cost of white lead, and the prices have been very firmly maintained. Red lead opened at a minimum of 7 cts. and reached 9¾ cts. in March, that figure continuing in force up to the close of the year. Litharge opened at 6½ cts. and by March 17 advanced to 9¼ cts., which has since been the prevailing price.

IMPORTS OF LEAD PIGMENTS INTO THE UNITED STATES

Year.	Red Lead.		White Lead.		Litharge.		Orange Mineral.	
	Pounds.	Value.	Pounds.	Value.	Pounds.	Value.	Pounds.	Value.
1901.....	485,466	$19,369	384,671	$21,226	49,306	$1,873	977,644	$52,409
1902.....	1,075,839	37,833	506,423	25,320	88,115	2,908	997,494	49,060
1903.....	1,152,715	40,846	453,284	24,595	42,756	1,464	756,742	36,407
1904.....	836,077	30,115	587,383	33,788	44,541	1,500	766,469	37,178
1905.....	704,402	26,553	597,510	34,722	117,759	4,139	628,003	31,106
1906.....	1,093,619	50,741	647,636	41,233	87,230	3,737	770,342	42,519
1907.....	679,171	35,959	584,309	37,482	90,475	4,386	615,015	37,799
1908.....	645,073	28,155	540,311	30,451	96,184	3,327	485,407	26,645
1909.....	760,179	30,428	694,599	39,963	90,655	3,740	496,231	27,562
1910.....	822,289	32,750	686,052	38,919	48,693	2,252	600,461	32,199
1911.....	1,163,533	46,170	741,071	46,213	24,662	1,196	504,734	28,515
1912.....	757,908	33,854	687,705	46,494	32,443	1,550	334,551	20,914
1913.....	99,832	4,903	672,109	45,266	34,023	1,750	330,525	22,205
1914	13,554	2,907	596,567	40,213	33,651	1,805	240,388	16,388
1915.....	1,968	142	239,187	24,608	20,650	1,422	171,572	14,061
1916.....	20,467	5,302	88,617	8,050	1,320	150	70,934	8,781

Silver-lead Smelting Works of North America[1]

The accompanying list which has been corrected to Dec. 1, 1916, gives the several silver-lead smelting works of the United States, Mexico and Canada, together with the number of their furnaces (in all cases, blast furnaces) and their estimated annual capacity in tons of charge. By "tons of charge" is meant ore and flux, but not coke. The ton of charge is manifestly the correct unit. In the case of a self-fluxing ore, the ton of ore smelted and the ton of charge smelted is the same thing. In other cases fuel and labor have to be used in smelting the flux as well as in smelting the ore, and the economy of smelting depends largely upon the percentage of ore in the charge. The management of this question is about the highest exercise of the metallurgist's skill.

[1] *Eng. Min. Jour.*, Jan. 6, 1917.

The figures in the accompanying table are in most cases from official communications of the respective companies. Estimated capacity is always a matter of more or less uncertainty, and for this reason the figures given ought to be accepted only as approximations.

AMERICAN SILVER-LEAD SMELTING WORKS

Company.	Place.	Furnaces.	Annual Capacity (*).
American Smelting and Refining Co................	Denver	7	510,000
American Smelting and Refining Co................	Pueblo	7	380,000
American Smelting and Refining Co................	Durango	4	210,000
American Smelting and Refining Co................	Leadville	10	510,000
American Smelting and Refining Co................	Murray	8	657,000
American Smelting and Refining Co................	East Helena	4	306,000
American Smelting and Refining Co................	Omaha (†)	2	82,000
American Smelting and Refining Co................	Chicago (†)	1	36,000
American Smelting and Refining Co................	Perth Amboy (†)	4	170,000
Con. Kansas City Sm. and Ref. Co.................	El Paso	6	380,000
Bunker Hill & Sullivan Min. and Concentrating Co...	Kellogg, Ida.	..	§
Selby Smelting and Lead Co........................	Selby	3	210,000
Ohio & Colorado Smelting Co......................	Salida, Colo	4	345,000
United States Smelting Co.........................	Midvale, Utah	7	530,000
eedles Smelting Co...............................	Needles, Cal. (‡)	2	70,000
orthport Smelting and Refining Co................	Northport, Wash.	3	250,000
ennsylvania Smelting Co..........................	Carnegie, Pa.	2	60,000
International Smelting Co.........................	Tooele, Utah	5	600,000
Totals, United States............................		79	5,306,000
American Smelting and Refining Co................	Monterey	10	584,000
American Smelting and Refining Co................	Aguascalientes	1	40,000
American Smelting and Refining Co................	Chihuahua	7	400,000
American Smelters Securities Co..................	Velardeña	3	150,000
Compania Metalurgica Mexicana...................	San Luis Potosi	10	250,000
Compania Metalurgica de Torreon..................	Torreon	8	360,000
Compania Minera de Penoles......................	Mapimi (‡)	6	325,000
Totals, Mexico..................................		45	2,109,000
Consolidated Mining and Smelting Co..............	Trail, B. C	4	140,000

* Tons of charge. † Smelt chiefly refinery between-products. ‡ Not being operated. § Plant under construction.

The total capacity of the Mexican works is a little over 2,000,000 tons per year; of the American works, a little over 5,000,000 tons. With respect to the American works, such capacity has never been in use at one time. More or less of it represents capacity idle because of changes in the conditions of ore supply.

There were no new producers of refined lead in 1916, but there was one new smelter, viz., the Northport Smelting and Refining Co., which operated a plant of four blast furnaces at Northport, Wash., smelting ore from the Hercules and allied mines in the Coeur d'Alene. This lead was refined by the Pennsylvania Smelting Co. at Carnegie, Penn. The Bunker Hill & Sullivan Co. commenced the erection of a smeltery and refinery at Kellogg, Idaho.

PRIMARY LEAD SMELTED OR REFINED IN THE UNITED STATES[1]
(Short tons) (Apportioned according to source of ore)

	1908.	1909.	1910.	1911.	1912.	1913.	1914.	1915	1916.
Domestic Ore:									
Alaska	3	69	75	51	45	6	....	358	659
Arizona	1,464	1,507	948	3,428	3,891	4,901	5,602	6,953	15,328
Arkansas	....	14	....	15	....	....	52	51	170
California	515	977	1,207	615	811	3,294	3,698	5,606	3,633
Colorado	28,729	30,865	38,542	30,442	37,039	42,840	41,198	32,352	33,046
Idaho	98,464	103,747	109,951	117,335	127,780	137,802	177,827	160,680	170,059
Illinois	362	273	263	308	513	619	427	910	670
Iowa	110	15	....	....	....	....	34	....	....
Kansas	2,293	2,763	1,308	2,522	1,937	1,504	1,043	1,320	1,737
Kentucky	....	....	50	....	91	16	16	95	37
Missouri	122,451	141,105	161,659	182,203	162,610	152,430	194,275	195,634	218,253
Montana	2,320	1,451	1,943	2,484	2,517	3,256	4,386	4,853	4,961
Nevada	3,796	4,792	2,246	1,082	5,699	6,142	5,996	7,664	11,858
New Mexico	586	1,350	1,890	1,371	2,511	1,821	741	2,157	3,290
North Carolina	....	....	2	35	34	10	....	....	....
Oklahoma	1,409	2,268	1,805	1,925	2,500	3,214	3,916	4,346	10,969
Oregon	7	7	....	11	21	37	17	11	9
South Dakota	13	....	8	33	12	7	2	5	12
Tennessee	....	....	....	....	....	....	....	8	....
Texas	42	44	36	57	30	108	89	111	26
Utah	42,455	66,648	60,605	54,933	60,664	71,069	88,976	106,105	111,789
Virginia	13	....	87	400	85	878	143	457	740
Washington	391	120	339	612	53	9	2	11	217
Wisconsin	4,013	3,252	3,909	3,966	3,301	2,639	1,818	2,632	3,121
Undistributed	36	317	101	48	120	63	99	131	159
Zinc residues	1,290	1,735	2,237	1,987	3,131	3,765	4,125	4,567	5,478
Total from domestic ore.	310,762	363,319	389,211	405,863	415,395	436,430	534,982	537,012	596,221
Foreign Ore:									
Africa	....	3,150	3,310	582	1,774	5,976	2,942	....	328
Canada	162	66	25	122	29	16	2	1,174	1,231
Central America	12	20	3	28	....	....	....	1	7
Mexico	10,145	16,944	11,704	7,333	7,407	4,512	2,386	5,437	1,917
South America	1,186	1,536	2,996	2,677	2,332	2,617	1,821	2,829	2,366
Other foreign	4	38	27	22	30	102	488	140	236
Foreign Base Bullion:									
Canada	179	1,500	....	....	....	....	....	....	1,072
Mexico	73,210	70,816	76,805	84,220	76,805	37,359	21,689	33,173	11,598
South America	....	....	....	....	....	....	....	275	....
Total from foreign ore and base bullion.	84,898	94,070	94,870	94,984	88,377	50,582	29,328	43,029	18,906
Grand total, derived from all sources.	395,660	457,389	484,081	500,847	503,772	487,012	563,810	580,041	615,127

Lead in the United States

Alaska.—The lead production in Alaska in 1916 amounted to 659 tons, the largest production recorded from the territory.

Arizona.—The lead production in Arizona increased from 6953 tons in 1915 to a record production of 15,328 tons in 1916. The Copper Queen and Shattuck-Arizona mines, in the Warren district, and the Tennessee mine, in Mohave County, continue to contribute the largest part of the lead output.

California.—The 1916 production amounted to 3633 tons, as compared with 5606 tons in 1915 and 3698 tons in 1914.

Colorado.—The lead production in Colorado was 33,046 tons in 1916

[1] U. S. Geol. Surv.

as compared with 32,352 tons in 1915, 41,198 tons in 1914 and 42,840 tons in 1913.

Idaho.—The output of lead increased from 160,680 tons in 1915 to 170,059 tons in 1916. The value of the lead output increased from $16,-261,975 to $24,616,000, or about 51 per cent. There were important increases at the Morning, Hercules, Hecla, and Interstate-Callahan mines. The Hecla opened a new and important ore-body, and the Morning is said to be developing into a larger mine at depth. The Bunker Hill output was normal, but the output of the lead mines of the Yreka district was generally less than 1915, especially as the Stewart ceased shipments early in the year. The lead smelting plant at Northport, Washington, was operated especially on Hercules ore and concentrates, from March to the end of the year. At Kellogg, foundations for the new 900-ton lead plant were being laid, and Idaho will soon have a smelting plant in the Coeur d'Alene region. In Lemhi County, lead shipments came from the Pittsburg Idaho, Latest Out, and Gilmore; in Fremont County, from the Wilbert, and in Bonner County, from the Idaho Continental, where a new mill was completed. Mills were constructed at the Silverado, Alhambra, Hypotheek, Constitution, and Ray Jefferson, and the Rex mill was improved. The Coeur d'Alene region made shipments of concentrate and crude ore at the rate of 45,000 tons per month, of which about 35,000 tons was lead material and the remainder zinc ore and concentrate.

Production figures are not yet available covering the yield of the Coeur d'Alene district[1] during 1916, but it is believed that the production of lead and silver will not be materially increased, if at all, over that for 1915.

The reason why the high prices for the metals have not resulted in a larger output is because of the near exhaustion of several of the producers and the temporary closing of the properties of the Sierra-Nevada Consolidated Mining Co. and the Tamarack & Custer Mining Co. The Morning mine, of the Federal Mining and Smelting Co., will show a considerably larger yield than in former years, as will also the Hecla, and a moderate increase will be recorded for the Bunker Hill & Sullivan.

A great deal of prospecting work has been energetically carried on throughout the entire year, and apparently the public is giving substantial support to such development by the purchase of treasury stock in various development companies and the payments of assessments where needed to carry on the development of non-producive properties. No new producers of lead ore came in during 1916. There were some occasional small shipments of an experimental character. The Ray Jefferson zinc-silver-lead property on the western slopes of Sunset Peak began

[1] Stanley A. Easton, *Eng. Min. Jour.*, Jan. 6, 1917.

milling during the early fall. The product of this plant is being stored awaiting the completion of the branch of the Oregon-Washington Railroad and Navigation Co. up Beaver Creek, which will give railroad transportation direct from the Ray Jefferson concentrator.

The production of metallic lead at the mine by an electrochemical method in a small experimental way was carried on throughout the year by the Bunker Hill & Sullivan Co. and is the first metal of all the millions of pounds yielded by the district to be locally reduced. The entire output of the Hercules mine for the year was smelted at Northport, Wash., in the rebuilt plant recently put into commission there by the Northport Smelting Co., entirely owned and operated by the owners of the Hercules in connection with their lead refinery at Carnegie, Penn. Ground was broken in June for the Bunker Hill smelter and excellent construction progress made. A large portion of the necessary equipment is on the ground, and it is expected to begin operations at this plant early in the spring of 1917.

The most important events of the year affecting the people of the district are prohibition and the bonus wage payments made by the producing companies to their employees beginning Feb. 1, 1916, and being: 25 cts. per shift when lead is 5 cts. per lb. and under 5½ cts.; 50 cts. per shift when lead is 5½ cts. per lb. and under 6 cts.; 75 cts. per shift when lead is 6 cts. per lb. and under 6½ cts.; $1 per shift when lead is 6½ cts. per lb. and over. This bonus is paid all employees without regard to what department they may be connected.

The other important event is the State statutory prohibition law applied Jan. 1, 1916; after being in effect until Nov. 7, the voters of the district overwhelmingly supported the constitutional prohibition amendment embodying the same provisions then submitted. The enforcement of this law has been reasonably effective, and the result of these new circumstances is being watched with much interest. At the present time the indications are that the new condition is resulting in a great deal of benefit both to the communities and to the mines.

Illinois.—The lead production in Illinois decreased from 910 tons in 1915 to 670 tons in 1916.

Kansas.—The lead production in Kansas in 1916 was 1737 tons as compared with 1320 tons in 1915 and 1043 tons in 1914.

Missouri.—Missouri still continues to lead in the lead production with an output of 218,253 tons in 1916, as compared with 195,634 tons in 1915 and 194,275 tons in 1914.

In the Joplin and associated zinc-lead districts, there was much activity in the early part of the year, but some curtailment later, owing to recession in the price of the principal metal, power deficiency and other causes. The American Zinc, Lead and Smelting Co. extended its holdings in the district, its most important acquisition being the Granby Mining and Smelting Co. Flotation concentration was extended to some of the leading mills. Outlying districts in Kansas, Oklahoma and Arkansas were the scenes of important development, particularly west of Baxter Springs, Kan., and extending northerly into the Oklahoma field. In Arkansas the Rush Creek section was busy, and interesting developments were made at the Hurricane mine by the J. C. Shepherd Mining Co., and the Fullbright in Marion County. The extension of the Fort Smith, Ark., gas field led to the building of new smelting plants there.

Southeastern Missouri[1] produced about 184,000 tons of pig lead in 1916, which approximated $25,000,000 in value and which is a new high record. It exceeds the previous banner tonnage of 1915 by only about 3 per cent., however, which suggests that the district is approaching its zenith, as hitherto the usual rate of increase has been surprisingly consistent at about 10 per cent. annually. The increase in value is unprecedented and the profits realized by the operators were most substantial in spite of high operating costs. The St. Louis lead market was the highest since the Civil War, as it ranged from 5.7 to 8.25 cts., averaging about 6.89 cts. per lb., or $138 per ton of lead (2000 lb.), with the December market closing at 7.50 to 8.00 cts.

As Madison County, which adjoins St. Francois County on the south, materially increased its output in 1916, the very great predominence of St. Francois County was not so marked as usual, yet it produced over 90 per cent. of the district's production. Washington, Franklin and Jefferson Counties contributed small scattering tonnages from the old shallow diggings, the aggregate of which was trifling when compared with the production of the deeper disseminated deposits of the big mines in St. Francois County. Yet it is well within the memory of the old miners when St. Francois County was a similar small, erratic producer from "gopher-holes" and was a smaller lead contributor than the adjoining Washington County. Interest is at last slowly awakening to the fact that the early history of St. Francois County was identical with the present condition of Washington County, in spite of the enormous differences in their present relative importance as lead producers. Appreciation is being shown that the most important factor in the modern development of St. Francois County was the intimate relation between the small, erratic, shallow deposits and the deep, large, low-grade disseminated deposits. While the disseminated deposits are not always found immediately under the shallow "diggings" in St. Francois County,

[1] H. A. Wheeler, *Eng. Min. Jour.*, Jan. 6, 1917.

the close proximity of the two is highly noteworthy and it is impossible to recall an instance in St. Francois County where the shallow "diggings" were not a trustworthy guide in approximately locating the disseminated ore-bodies. This was so promptly recognized by the earlier workers that the "old diggings" were long ago corralled, even in advance of testing them with the diamond drill, and the present-day prospector has to grope after new discoveries without their valuable guidance.

That this same intimate relationship between the "shallow lead" and the deeper disseminated deposits will be found true in Washington County is receiving more attention and the next 5 years will probably witness marked activity in deep drilling in Washington County that is likely to result in very important developments.

Labor has enjoyed its share in the prosperity and wages are decidedly the highest ever known in the district. It is a sad commentary, however, that the increase in incomes is mainly going into better living and luxuries and very little is being saved for the inevitable "rainy day." In one town of scarcely 5000 there are over 125 automobiles, most of which are of a more expensive class than Fords, and the volume of gasoline sales would excite the envy of a much larger place.

Although the district is in a hilly country, being on the flanks of the Ozark uplift, the most striking and obtrusive features of the district are the enormous piles of tailings that now loom up as the most impressive feature of the landscape. They are not only silent, huge monuments that attest tremendous activity, but they are also eloquent warnings that the diamond drill must be more active in the future to replace the ore-bodies that are being rapidly exhausted by the modern large mills. With the higher prices prevailing for lead, it has been possible to work ores carrying only 2 per cent. of lead with profit, but the temptation to take advantage of the "creamy" lead market caused the operators to keep the average-tenor of the ore to a slightly better yield than 3 per cent. of pig lead last year. Tailings that were made by the old, small mills when the ores were yielding 6 to 12 per cent. would to-day be regarded as highly profitable ore, but the much greater skill now being utilized in the management and operation of the large, modern plants under able technologists will enable the district to make even larger profits on the much lower grades that will have to be worked in the future.

The veteran St. Joe Lead Co., which was the pioneer in developing the disseminated deposits, continues as the most important of the Missouri lead producers and is undoubtedly the largest in the world. Since it absorbed the Doe Run Lead Co., with which it was always intimately affiliated, it has become the preëminent producer of the district.

The past year has been the most prosperous in its long career of about half a century, and besides paying dividends aggregating $3,523,685, from the largest tonnage ever produced, it paid off a lot of notes and debts.

While only nine shafts were operated, or less than formerly, a larger tonnage was extracted in spite of the concentration of hoisting to fewer points. The three mills operated were the 2000-ton mill at Bonne Terre, the 2000-ton mill at Leadwood and the 4000-ton mill at Rivermines, the latter taking care of the output of the shafts of the former Doe Run Co.

A retaining reservoir covering over 40 acres is being built at Bonne Terre on the site of the golf grounds that will be used for impounding the slimes and thus avoid the contamination of Big River that caused damage suits by the farmers. A dam is being built with mill tailings. A new electric power plant that is centrally located is being built at Rivermines that will replace the gas engine and producers at Rivermines and Bonne Terre.

The smelting works at Herculaneum are being made more efficient and now have a capacity of 8000 tons of pig lead monthly. A larger power plant is to be installed, the Cottrell process for precipitating fume is to be introduced and the double-roasting system on Dwight & Lloyd machines is to be employed to improve the roasting. As the yard space for dumping the molten slag from pots is about filled up, the slag will be granulated by water and sold for railroad ballast. The normal force of 550 men has been increased to 800 on account of the extensive construction work.

The Desloge Lead Co. had a very successful, prosperous year and operated to full capacity from three shafts. The mill was enlarged and improved and the tailings are now stacked close to the mill by an endless belt conveyor, instead of being hauled away by railroad trains to be dumped in the valleys. An Oliver filter was recently installed to dewater the flotation product and two steam turbines were added to the power plant. The small historic Flintshire furnaces that have been operated over 35 years were shut down last summer, although for many years they have treated but a minor portion of the output, as the major portion has been treated by custom smelters at Alton, Collinsville, etc.

The National Lead Co. was quite aggressive in searching for new ore-bodies by optioning and drilling unabsorbed properties and was rewarded with two good discoveries. The Hill tract of 120 acres, that is 1½ miles north of the Baker mine, was taken over under a drilling option at $500 per acre. It is located on the Leadwood branch of the M. R. & B. T. R. R. The famous 600-acre Pim tract, in the high flint hills south of Flat River, that was supposed to be beyond the Flat River basin, was taken over at $275 an acre after developing a large ore-body with the diamond drill at 500 to 800 ft. This tract went begging in the early days at $10 an acre and was regarded as absolutely hopeless by the old-timers, as it is covered by the "Potosi" formation, under which even a former State geologist thought there was no hope of finding disseminated lead.

The mill is treating 3000 tons and is to be increased to 4000 tons per diem by the end of the year. When it was built in 1900, it had a capacity of 1500 tons and was the largest and finest in the district; the doubled tonnage has been obtained without material enlargement of the building. The power plant, which adjoins the mill, is being enlarged. The local railroad to the shafts is now operated with steam locomotives, which have replaced the trolley motors, as the latter were found to be too erratic and severe on the power service, in spite of large storage batteries.

The Federal Lead Co. had a very busy year and made a new high record to a depth of 459 ft. on the old Central tract, about ¼ mile east of Elvins and is now an important producer from a large ore-body that was blocked out with diamond drills.

A new mill, No. 4, of 3000 tons daily capacity was started last March at this shaft and promises to be the model plant of the district. It is constructed of reinforced concrete and is lighted with an unusual number of windows—a feature that is often neglected and which is important to secure good results in concentration. The ore from No. 12, or the new shaft, is conveyed to the mill by endless belts, after passing through an independent rock house equipped with two large gyratory crushers that feed to disc-crushers. The mill is equipped with Hancock jigs, trommels, drag classifiers, dewaterers, regrinding mills, rolls, 40 tables, Dorr thickeners, a flotation unit, Oliver filter and drying plant. The tailings will be moved by a belt conveyor to a neighboring valley. The mill is of the gravity type, being built on a side hill, and the first of the two units is expected to start this month after many delays in the freight deliveries.

The Baker Lead Co., which operates the Jake Day tract on Big River and is owned by Boston interests, had an active year. It is shipping 600 tons daily from its single shaft to the mill of the National Lead Co., 10 miles distant, where it is milled by this company under a special contract.

The Boston Elvins Lead Co., which purchased, for $100,000, the Jones tract of 40 acres, 1 mile southeast of Elvins, completed the sinking of its three-compartment shaft last month after a hard fight with an unusually large quantity of water—amounting at one time to 2500 gal. per min. The shaft is 571 ft. deep and is being equipped with a hoisting plant. The ore will be shipped to the National mill for treatment, 3 miles distant, over the M. R. & B. T. R. R.

The Mine La Motte property, the oldest lead mine in the United States, had the most active year in its history and the output made a new high record. Under the new management, the steam shovel has become an active factor in reworking the surface clays that have been more or less gophered over by the "patch diggers" for the past two centuries. This shovel work produces more or less coarse "chunk" galena that was overlooked by the early miners and a sand containing 80 per cent. silica that carries 3 to 8 per cent. of carbonate of lead; the latter is shipped direct to the smelters for fluxing purposes.

The lower or disseminated deposits are also being worked, which on this property are very shallow, or only 50 to 200 ft. deep, with little or no water in the underlying sandstone. It is proposed to mine them by open cuts with steam shovels and utilize the great excess of barren rock for ballast, riprap, etc. A railroad is proposed to the Mississippi River, about 35 miles east, to secure cheap barge water to the Southern markets, where good rock is scarce.

At Annapolis, 25 miles southwest of Fredericktown, in Iron County, (which adjoins Madison County on the west and St. Francois County on the south) the Balch property has been taken under option, on which the Federal Lead Co. found disseminated lead in several holes. In this district, the hills are of granite and porphyry, while the valleys or basins are filled with the "Bonne Terre" or lead-bearing limestone. As the valleys are narrow and small, they have been but slightly prospected, as the outlook is not encouraging for large ore-bodies, and no lead mines have thus far been developed.

Montana.—The output of lead increased from 4853 tons in 1915 to a new record of 4961 tons in 1916. A great part of this output came from lead concentrates made from lead-zinc ore at Butte and from residues resulting from the smelting of zinc concentrates from the Butte district. Part of the lead output came from the Iron Mountain mine, in Mineral County, which was operated by the Federal Mining and Smelting Co. until August. A mill was constructed at the Banner & Bangle property, near Troy, to treat lead-zinc ore.

Nevada.—The production of lead increased from 7664 tons in 1915 to 11,858 tons in 1916. A considerable part of this production came, as in former years, from the mines of the Yellow Pine district, in Clark County. The Prince Consolidated, at Pioche, greatly increased ore shipments, and a considerable output came from the Uvada property. Other important lead shipments were made from the Groom mine, in Lincoln County, Nevada Bunker Hill property, in Elko County, and the Union Mines, in Eureka County. At Eureka, considerable ore was shipped from the Richmond-Eureka and California Mining Co. property.

New Mexico.—The yield of lead showed an appreciable increase. The production in 1916 was 3290 tons, as compared with 2157 tons in

1915. Lead ores were shipped from the Central, San Simon, and Pinos Altos districts, Grant County, and Cooks Peak and Victorio districts, Luna County. Considerable tonnages of lead carbonate ore were shipped from Kelly, Socorro County.

Oklahoma.—The lead production in Oklahoma increased from 4346 tons in 1915 to 10,969 tons in 1916. Development was active in the Oklahoma districts and the extended area of proved territory insures a larger future output under normal conditions. Many new mills were built or were under construction during 1916 and the period of mill construction has not ceased.

Utah.—Lead production surpassed all former records, increasing from 106,105 tons in 1915 to 111,789 tons in 1916. A large increase in the output of lead was made from the mines at Bingham. The principal producers were the Utah Apex, United States, Highland Boy, New Haven, and Dalton and Lark properties. The production of lead from the Tintic and Park City districts was not much greater than in 1915.

The Salt Lake Valley smelteries ran at capacity throughout the year. The American Smelting and Refining Co. at Murray had six furnaces treating lead ores. The United States Smelting Co. at Midvale ran five furnaces on lead ore. Among other improvements this company built a brick thawhouse with a capacity of 12 cars to take care of ore frozen in the cars during winter delivery.

All the camps—Bingham, Tintic, Park City, Beaver County, Stockton, Ophir, Big Cottonweed, Alta and American Fork—showed much activity.[1] Several new mills were built, and the capacity was added to in old ones. Construction was started on a new railroad into Deep Creek in Tooele County, a relatively undeveloped mineral section of the State. It is expected to be in operation early in 1917. Development work was done in the Dugway district, 60 miles east of Deep Creek, and some shipments of high-grade lead-silver ore were made.

At Park City there were 20 shippers, as compared with 18 in 1915. A greater tonnage of ore than usual was milled in the camp and resulted in an increased proportion of concentrates. The Silver King Consolidated built a 2-mile aërial tram and bought and remodeled the old Grasselli mill for its low-grade ores. The Big Four Exploration Co. increased the capacity of its mill for tailings treatment to 1000 tons and made arrangements for installing 750-ton flotation equipment early in 1917. The Broadwater Mills remodeled its 600-ton plant, installing flotation equipment. Two small mills were built to treat tailings.

At Alta the Wasatch mines began a new 5000-ft. drainage and operating tunnel, to unwater the old Columbus Consolidated stopes now

[1] E. R. Zalinski, *Eng. Min. Jour.*, Jan. 13, 1917.

owned by this company, which had good ore showings when flooded. This tunnel will eventually be extended to drain other properties. The largest shippers from Alta were the South Hecla and the Michigan-Utah. Numerous lessees operated.

In Big Cottonwood the Cardiff was the principal shipper, averaging 100 tons of silver-lead-copper ore a day in the good hauling season. In American Fork, the Pacific mine—under lease to the Fissures Exploration Co.—built and began operating a 50-ton mill and made shipments of lead-silver and copper ores. An electric power line was built by the Utah Light and Power Co. from Snake Creek into the camp. The Dutchman, Belerophon, Earl-Eagle, Red Cloud, Miller Hill and other properties operated. The combined output of Alta, Big Cottonwood and American Fork is estimated at 47,000 tons. About half of this was from Big Cottonwood and was hauled by wagons and tractors.

A heavier tonnage was shipped from the old camp of Ophir, where there were more shippers than in many years. The Ophir Hill Consolidated, Cliff, Ophir Coalition, Lion Hill, Buffalo Consolidated and various lessees made shipments over the St. John & Ophir R.R., aggregating 126,000 tons of ore and concentrates. At Stockton the Hidden Treasure, Mono, Bullion Coalition and other properties and lessees shipped silver-lead and zinc ores amounting to about 19,000 tons. Beaver County had more shippers and more properties operating than ever before. Among these were the Moscow, Montreal, Majestic, Lincoln, Creole, Commonwealth, Rattler, Horn Silver, Paloma, Cedar-Talisman and others. Lead-silver, copper and zinc ores were shipped. The flotation mill of the Caldo Mining Co. at Frisco treated tailings from the old dump at the Horn Silver mine and produced lead and zinc concentrates. At Newhouse the 650-ton plant of the Utah Leasing Co., treating tailings from the old Cactus dump by flotation, operated steadily and arranged to increase the capacity to 850 tons. The output of Beaver County is estimated at 65,000 tons. The Tintic Milling Co. enlarged its mill at Silver City—treating low-grade ores by chloridizing roasting and leaching—to a capacity of 300 tons daily. Several shipments of bullion were made. The Tintic Standard in East Tintic developed a body of lead-silver ore of shipping grade on the 1600 level and became a regular producer. The Eagle & Blue Bell continued its shaft to water level and opened up and developed large ore-bodies.

Virginia.—The Virginia lead production increased from 457 tons in 1915 to 740 tons in 1916. An important lead-zinc development was made at the old Holladay mine in Spottsylvania County by the Virginia Lead and Zinc Corporation, which made shipments and planned a 100-

ton mill. A mill was built for the Allah Cooper lead-zinc mine in Louisa County.

Washington.—The production of lead increased from 11 tons in 1915 to 217 tons in 1916, smelted or refined in the United States. In addition, 2001 tons of lead was smelted in Canada from ores from Washington. This notable increase was due largely to the discovery of lead at the Electric Point mine, near Northport. A number of chimneys of lead ore were opened in limestone; the ore is rich in lead, but extremely low in silver. The Bonanza mine at Bossburg also contributed lead ore. An important event of the year was the resumption of smelting operations at Northport, by the Northport Smelting and Refining Co. The ores treated were mainly those of the Day silver-lead mines in the Coeur d'Alene district of Idaho.

Wisconsin.—The lead production in Wisconsin has for a number of years been on the decline, but in 1915 production again took an increase, amounting to 2632 tons as compared with 1819 tons in 1914. The production in 1916 showed a further increase, amounting to 3121 tons. The Bentan district continued to be the largest producer, followed by Hazel Green and Livingston.

Lead in Foreign Countries

Australia.[1]—The Broken Hill Associated Smelters Proprietary Co., Ltd., has taken over the Broken Hill Proprietary works at Port Pirie. The new company is a coöperative institution for the smelting of silver-lead ores and concentrates, and the refining of the resultant silver-lead bullion. It has the largest silver-lead smelting works in the world, having a capacity to make an output of 200,000 tons of pig lead, and 5,000,000 to 6,000,000 oz. of silver per annum. The plant is also capable of handling large quantities of gold ores, concentrates, and other auriferous materials. The addition of a large silver, lead, and gold refinery is in hand at Cockle Creek, New South Wales. When erected, this plant will make the Sulphide Corporation self-contained. In the past this company's auriferous and argentiferous bullion was shipped to England for treatment.

Bolivia.[2]—Lead exports from Bolivia during the first 4 months of 1916 amounted to 839 metric tons. In the whole of 1915 the total was 2208 tons, and in 1914, 1555 tons. The following countries purchased Bolivia's lead production in 1915: Great Britain, 1731 tons; United States, 287 tons; and Argentina, 190 tons.

Canada.[3]—Notwithstanding the demand and high prices, the actual recovery of lead as bullion and refined was less than during 1915. The

[1] *Min. Jour.*, Oct. 21, 1916.
[2] *Min. Sci. Press*, Sept. 9, 1916.
[3] Preliminary Report of the Mineral Production of Canada for 1916. Department of Mines, Canada.

LEAD PRODUCTION OF THE WORLD

(In metric tons)

Year.	Australasia. (a)	Austria. (a)	Belgium. (a)	Canada. (a)	France. (a)	Germany. (a)	Greece. (a)	Hungary (a)	Italy. (a)
1902..	90,000	11,264	19,504	10,411	18,817	140,331	14,048	2,243	26,494
1903..	106,006	12,162	22,263	8,226	23,258	145,319	12,361	2,057	22,126
1904..	117,895	12,645	23,470	17,241	18,800	137,580	15,186	2,104	23,475
1905..	106,418	12,968	22,885	25,391	24,100	152,590	13,729	2,146	19,097
1906..	93,557	14,846	23,765	24,580	25,614	150,741	12,308	1,925	21,268
1907..	96,608	13,598	27,450	21,660	24,800	164,079	13,814	1,468	22,978
1908..	119,207	12,669	35,650	19,593	26,112	164,079	15,892	1,544	26,003
1909..	77,992	12,941	40,306	23,295	26,927	167,920	14,948	1,590	22,133
1910..	105,897	15,476	40,715	14,967	20,226	159,851	16,710	2,077	14,495
1911..	105,397	18,097	44,308	10,791	23,635	161,287	14,234	1,583	16,684
1912..	113,710	19,993	54,940	16,226	31,080	192,618	14,498	1,605	21,450
1913..	(d)116,000	22,312	35,750	17,089	(d) 28,000	(d)181,100	18,309	(e)1,790	21,674
1914..				16,487			20,684	1,368	20,464
1915..				21,009			11,595		21,812
1916..				18,866					

Year.	Japan. (a)	Mexico. (a)	Russia. (a)	Spain. (a)	Sweden. (a)	United Kingdom. (a)		United States.	Totals. (f)
						Foreign Ores.	Domestic Ore.		
1902.	1,644	106,805	225	177,560	842	9,113	17,987	254,682	901,970
1903.	1,728	(b) 94,181	106	175,109	678	14,900	20,278	256,138	916,896
1904.	1,803	(e) 95,010	90	185,862	589	6,888	20,155	278,634	957,427
1905.	2,272	(b)101,196	700	185,693	576	7,517	20,977	290,472	988,727
1906.	4,305	(b) 73,699	907	185,470	753	6,984	22,691	323,567	986,980
1907.	3,067	(b) 76,158	520	(d)185,800	813	10,880	24,850	322,854	1,011,397
1908.	2,910	(b)127,010	523	188,062	277	11,480	21,336	284,858	1,057,205
1909.	3,429	(b)118,186	(d) 790	179,993	166	8,056	22,822	329,690	1,056,326
1910.	3,907	(b)120,662	(d)1,200	190,523	355	8,933	21,866	353,186	1,093,043
1911.	4,160	(b)124,605	(d)1,000	189,810	1,134	10,048	18,279	368,301	1,108,880
1912.	3,613	(b)109,717	(e)1,000	232,612	1,073	(e) 8,255	19,473	376,947	1,212,252
1913.	(d) 3,600	(b) 55,530	(e)1,000	(d)203,000	1,235	(d)30,500	18,462	396,034	1,142,264
1914.	4,563				1,396		19,684	485,011	
1915.	4,764			(e)190,000	1,918		15,767	487,177	
1916.				(b)173,343			(e)12,500	540,892	

(a) From official reports of countries unless otherwise denoted. (b) Exports. (d) As reported by Metallgesellschaft, Frankfurt am Main. (e) Estimated. (f) The totals may be high on account of duplications which cannot be eliminated. (g) From *Eng. Min. Jour.*

total production in 1916 of lead in bullion credited to Canadian mines and estimated as recoverable from ores exported was 41,593,680 lb., a decrease of over 10 per cent. The 1916 production included 38,838,372 lb. of lead in bullion, of which a large portion was electrolytically refined, and 2,755,308 lb. recoverable from ores exported. The lead bullion was produced chiefly at Trail with small contributions from smelters at Kingston and Galetta, Ont. The lead ores exported were derived from Notre Dame des Anges, Que.; Hollandia mine, Bannockburn, Ont.; Surprise mine, Slocan, B. C.; and the Silver King mine, Mayo, Yukon district.

Although the recoveries of lead were small in 1916, shipments of lead ores from mines appear to have been greater than in the previous year.

Lead-ore shipments in 1916 were approximately 82,000 tons, containing 51,083,000 lb. of lead, while zinc-lead ores shipped to Trail contained considerable quantities of lead which would be recoverable in large part after the extraction of the zinc.

During 1916 improvements and additions were made in the lead department of the smelting and refining works at Trail, B. C. At Galetta, in southeastern Ontario, considerable prospecting and development work was carried on in deposits of galena in the last few years. Early in 1916 a small concentrating plant was put in operation, and construction of a mechanical hearth smeltery was begun to handle the concentrates. The first hearth was placed in operation in October. This plant was described in the *Engineering and Mining Journal* for April 28, 1917.

China.[1]—It is difficult to get any exact idea of the production of lead in China, as a good deal of the lead ore is smelted with silver ores, the bullion cupelled, and the litharge thus produced is converted into red oxide and sold as pigment. The largest single producer is the Shui-Kuo-Shan mine, in Hunan. Prior to the war, its products were under contract to go to Carlowitz & Co., of Hankow, but as they have been unable to fulfill their engagements in this respect, the Hunan Mining Board has decided to erect a smelting plant at Sungpo capable of turning out 100 tons of lead and zinc per day. The mines have been worked for centuries, and lately at the rate of 50,000 to 60,000 tons per annum. The ores contain galena, blende, iron and copper pyrites and occur at or near the contact of syenite and limestone.

Great Britain.—The preliminary production figures for 1916 report a lead-ore production of 17,084 long tons, as compared with 20,744 tons in 1915, and 26,013 tons in 1914.

Imports of lead (pig and sheet) in 1916 were 157,985 tons. Exports of English lead were 40,393 tons for the year.

The following table gives the imports of lead into England from the principal exporting countries:

	1912.	1913.	1914.	1915.
Spain	75,466	77,596	93,145	99,155
Australia	60,292	72,252	68,519	83,221
United States	28,279	24,155	31,048	52,058
Mexico	17,757	10,380	1,735	250

The Ministry of Munitions has restricted dealings in lead from Feb. 2, 1917. All dealings, except for execution of existing contracts, and all use, except for repairs and in quantities under 1 cwt., are permitted only under license.

[1] *Eng. Min. Jour.*, June 17, 1916.

An extended article on the mines of the Weardale Lead Co. appeared in *The Mining Magazine* for January, 1917. The holdings comprise some 85 square miles in County Durham. It is stated that the property has been a consistent producer for 8 centuries and is still the largest lead producer in Great Britain. In the period from 1884 to 1916 the total output has been 117,222 tons of ore. The ore is dressed at the mines and then smelted by the old Scotch ore-hearth method. Fluorspar is obtained in quantities about equal to the lead ore.

India.[1]—The Bawdwin mine of upper Burma, owned by the Burma Corporation, Ltd., is probably the greatest body of silver-lead-zinc ore whose exploitation has been successfully consummated in the last decade. The Tiger tunnel, the main opening of the mine, was expected to be completed by September. In the years past, the smelter has been employed largely upon old Chinese slag using only about 10 per cent. mine ore with 90 per cent. slag. With the approaching exhaustion of this slag, however, the proportion of mine ore in the charge has been increased to 50 per cent. in recent months.

During the year mine development work has been carried on, bringing the total proved ore to 2,085,000 tons, and the probable ore to 765,000 tons. The anticipated ore is now placed at 650,000 tons, bringing the probable total in the mine above the Tiger tunnel to 3,500,000 tons. A plant for the treatment of 1000 tons of ore per day is now being designed.

During 1915 the mine produced 14,000 tons of lead and the output for 1916 is expected to be just as great.

Italy.[2]—The lead-mining region of the Rome consular district is known as the "Mineral district of Iglesias," in the island of Sardinia. The argentiferous lead ore found in Sardinia is composed principally of galena, the sulphide of the metal, and a small proportion of carbonate of lead. The production of lead ore for the whole of Italy and the figures for the Iglesias district during the past 2 years were: Italy—41,590 metric tons in 1915; 43,538 tons in 1914. Iglesias district—40,829 tons in 1915; 42,878 tons in 1914. It is not believed that this decrease is due to any scarcity of ore, as reports by the engineer for the mineral district of Sardinia indicate that recent explorations show large deposits. This being the case, it is safe to assume that more recent production has been larger.

Rhodesia.—Nearly all the lead used in this territory is in the form of acetate of lead, nitrate of lead, litharge and pigments. Prior to the outbreak of war, acetate of lead was used in all gold-mining cyanide works. As lead is a very necessary requisite in war, stocks of acetate of lead soon became very low. Certain experiments were carried out by the Modder-

[1] *Eng. Min. Jour.*, Aug. 5, 1916.
[2] *Comm. Rept.*, March 10, 1917.

fontein Dynamite Factory in the manufacture and use of nitrate of lead, and proving satisfactory, the Modderfontein works began manufacturing nitrate of lead on a commercial scale, using scrap lead which was available in the Union. Since then, however, lead has been regularly purchased from the Broken Hill mine, Northern Rhodesia. This mine has for about 12 months been producing about 100 tons of pig lead per month. At present it is all shipped to England with the exception of that sold to Modderfontein Factory. A new blast-furnace plant and power plant are being constructed and the furnaces are expected to be in operation by May, 1916. The combined capacity of the furnaces is 900 tons of lead per month.[1]

Siberia.—At the Ekibastus smelting works of the Irtysh Corporation, Ltd., construction work on the lead-smelting plant is well advanced. The smaller of the two blast furnaces should be ready to go into commission early in 1917 and the larger one during the summer. Adjacent to the lead plant a lead refinery is being erected. This plant will treat the lead concentrates received from the Ridder mine and the residues from the zinc retorts.[2]

Spain.[3]—The leading Spanish establishments for lead manufacture are those of Mazarron, Puertollano, and Penarroya. The works of Penarroya have four furnaces and reduce 100 to 110 tons of ore every 24 hr., producing 50 to 60 tons of lead. The lead contains 0.13 to 0.14 per cent. of silver and a minute percentage of gold. The great furnaces of Mazarron have condensing galleries of over 2.17 miles in length. About 200,000 tons of lead in bars are produced annually, and the lead industry of Spain is of great importance owing not only to the amount reduced but to the value of production and quantity exported. Spain is the most important country of Europe for lead production and stands next to the United States in the list of the world's lead-yielding countries.

Recent Improvements in Lead Smelting

By H. O. Hofman

Introductory; Physical Properties; Alloys; Compounds

Lead-Silver and Gases.—Stahl[4] gives a summary of our present state of knowledge of both the solubilities of certain gases in lead and silver, and of their chemical actions at different temperatures and pressures. Omitting the statements regarding chemical reactions, he finds that at ordinary pressures, the gases O, H, N, SO_2, CO and C_xH_y are insoluble

[1] *So. Afr. Min. Jour.*, Aug. 26, 1916.
[2] *Eng. Min. Jour.*, Feb. 10, 1917.
[3] *Supp. to Comm. Rept.*, Aug., 1916.
[4] *Chemiker Ztg.*, **39**, 885 (1915).

in Pb. As regards O, it is well known that Ag absorbs as much as 30 times its volume of O; the dissolving power is greatest at the melting point and diminishes with increase of temperature; solid Ag holds in solution very little O.

The gas SO_2 (see also Stahl, *Metall-Erz*, **12**, 501 (1915)), appears to be taken up by molten Ag and not given off upon solidification. As silver does not contain any SO_2, a chemical reaction must take place between Ag and SO_2, which may be expressed by $4Ag + 2SO_2 \leftrightarrows Ag_2SO_4 + Ag_2S$ when air is excluded, and by $4Ag + 2SO_2 + 2O_2 \leftrightarrows 2Ag_2SO_4$ when air is present; the salt Ag_2SO_4 is completely decomposed in air at 925° C.

The gases H, N, CO, CO_2, C_xH_y are not soluble in Ag.

Lead-Copper.—Bogitsch[1] found that Pb-Cu alloys when fused form two layers between the copper-contents of 34.5 and 87.0 per cent.; and that at 940° the layers disappear, forming a solution which shows the same values top and bottom. Waehlert[2] found 1025° C. to be the temperature at which a homogeneous solution was found between the limits of 19 and 21 per cent. Cu.

Lead-Tellurium.—The freezing-point curve of this series of alloys shows according to Kimura[3] an eutectic with 24 per cent. Pb freezing at 412° C., the chemical compound PbTe with 61.89 per cent. Pb freezing at 904° C., and an absence of solid solutions. The earlier investigations of Fay-Gillson[4] gave similar results, an eutectic with 21.50 per cent. Pb freezing at 400° C., and the chemical compound PbTe freezing at 917°.

Lead-Sodium and Lead-Thallium.—The heats of formations of some Pb-Na and Pb-Tl compounds have been determined by G. D. Roos;[5] the values in calories per gram are 10.9 for Na_2Pb_5; 16.9 for NaPb; 20 for Na_2Pb; and 765 for $PbTl_2$.

Lead-Thallium.—A process for separating the two component metals has been patented by J. B. Hanney.[6] Galena is to be vaporized in a hot atmosphere of gases such as CO_2 and N, the vapor is to be oxidized with air, and the fume then cooled gradually. Salts of thallium and of radioactive metals form mixtures with $PbSO_4$ which have lower melting points than the latter and can be separated from it by regulating the temperature. Volatilizing and cooling are to be repeated to increase the concentration of thallium and other rare metals.

Lead-Copper-Nickel Alloys.—This ternary system has been studied by N. Parravano and C. Mazzetti.[7] The pairs of metals Pb and Ni, and Pb and Cu are only slightly soluble in one another; the same is the case

[1] *Compt. rend.*, **161**, 416 (1915).
[2] Mineral Industry, **22**, 456 (1913).
[3] *Mem. Coll. Sci. Imp. Univ. Kyoto*, **1**, 149 (1915); *Jour. Soc. Chem. Ind.*, **34**, 1211 (1915).
[4] *Trans. Amer. Inst. Min. Eng.*, **31**, 527 (1901).
[5] *Zeit. anorg. Chem.*, **94**, 329 (1916).
[6] U. S. Patent 1,175,146, Mar. 14, 1916.
[7] *Gaz. chim. ital.*, **44**, 375 (1914); through *Jour. Inst. Metals*, **14**, 234 (1915).

with the ternary alloys. The ternary eutectic point coincides with the freezing point of lead.

Lead and Alkali Earths.—F. C. Frary and S. N. Temple have patented[1] a number of alloys of lead with small amounts of Ca, Mg, Sr, and Ba with or without the addition of Cu and Al which are said to excel antimonial lead in hardness and toughness.

TABLE I.—HARDNESS OF SOME LEAD ALLOYS

Added Metal.	Per Cent.	Quenched.	Annealed.	
		Brinell No.	Brinell No.	For 2 to 3 Hr. at Deg. C.
Sb	0.5	7.6–8.2	6.8–7.1	230
	1	9.8–9.9	9.5–9.7	
	2	10.7–10.9	15.1–16.5	
	4	13.6–13.9	14.0–14.3	
	8	16.8–17.3	15.8–16.1	
Sn	0.5	6.0–6.4	6.0–6.4	270
	1	6.8–6.9	6.6–7.2	
	2	8.0–8.1	7.4–7.9	
	8	10.6–10.9	11.3–11.4	230
Cd	0.5	9.1–9.2	8.9–9.4	270
	1	9.5–10.2	9.7–10.1	
	2	11.6–12.2	12.6–12.7	
	8	16.7–19.8	14.2–14.5	220
Mg	0.5	13.5–15.5	13.8–13.9	220
	1	17.9–19.6	16.3–16.4	
	2	22.3–22.6	19.8–20.9	

Hardness of Certain Lead Alloys.—Ludwick[2] investigated the hardness of some alloys of lead with Bi, Sn, Sb, Cd, Ag and Mg by means of the Brinell method. His results are given in Table I. Mg has the greatest hardening effect on account of the chemical compound $PbMg_2$; the hardening power of Sb, Cd, and Ag are similar; the alloy with 2 per cent. Sb upon annealing has its hardness increased to that of one with 8 per cent. Sb.

Red Lead.—J. Millbauer[3] has investigated the effects the impurities Ag, Bi, Zn, Fe, Sb, Cu found in market lead have upon the production and the properties of red lead.

Dissociation and Reduction of $PbSO_4$.—In the first part of his investigation, W. Mostowitsch[4] finds that $PbSO_4$ begins to give off SO_3 at 800° C.; that the speed of reaction is slow up to 950°, and quick above this temperature; that fusion takes place between 950 and 1000°; and that up to 1000° C. there is little volatilization of PbO. The data differ somewhat from those found by Hofman and Wanjukoff.[5] The dissociation temperature of $PbSO_4$ is not lowered in the presence of SiO_2. The decomposition

[1] U. S. Patents Nos. 1,158,671-2-3-4-5, Nov. 2, 1915.
[2] *Zeit. anorg. Chem.*, **94,** 161 (1916).
[3] *Chem. Ztg.*, **39,** 858 (1915).
[4] *Bull. Amer. Inst. Min. Eng.*, May, 1916.
[5] MINERAL INDUSTRY, **21,** 541 (1912).

affected by SiO_2 is not proportional to the amount present; the reverse appears to be the case, as the viscosity of the lead silicate formed retards the reaction. The most rapid decomposition accompanied by the lowest loss of lead by volatilization appears to take place with mixtures lying between the singulo- and bi-silicates, that is, mixtures containing from 10 to 15 per cent. SiO_2.

The reduction of $PbSO_4$ by C and CO is not as simple as is usually supposed because there are formed Pb and SO_2 besides PbS. Reduction by C begins at 550° C. and is accompanied by the liberation of SO_2 and Pb, the PbS formed acting upon unreduced $PbSO_4$; the speed of reduction is quicker at 630° than at 550° and is finished at 700° with the two residual products PbS and Pb. Reduction by CO begins at 600°, also with the liberation of Pb and SO_2; it is very active at 630°. The double reaction noted furnishes an explanation for the elimination of S as SO_2 in the reducing fusion of a lead blast furnace; in fact, in smelting the gray slag from the ore-hearth as much as 50 per cent. of the S is usually expelled. The sulphate-S of $CaSO_4$ in blast-roasted ore has also little influence upon the matte-fall, as $CaSO_4$ is either reduced at 800° C. to CaS, which enters the slag as sulphide, or is dissociated by SiO_2 at 1000° C., when CaO follows the same course.

Lead Sulphate and Sulphide.—According to W. Reinders,[1] $PbSO_4$ acting upon PbS in a closed tube does not set free Pb; there are formed intermediary basic sulphates, and only when the SO_2 is withdrawn does the basic salt act upon PbS and set free Pb. The reactions taking place at elevated temperatures may be expressed by $PbS + 7PbSO_4 = 4PbO.PbSO_4 + 4SO_2 - 4 \times 38{,}390$ cal.; $6PbS + 4PbO.PbSO_4 = 14Pb + 10SO_2 - 10 \times 54{,}324$ cal.; adding the two and omitting the intermediary product gives $7PbS + 7PbSO_4 = 14Pb + 14SO_2 - 696{,}800$ cal. or $PbS + PbSO_4 = 2Pb + 2SO_2 - 99{,}543$ cal.

Lead Arsenates.—The studies of these compounds by G. E. Smith[2] and C. C. McDonnell and C. M. Smith[3] deal mainly with wet preparations and the salts obtained by these methods. Of metallurgical interest is the lead metarsenate, $Pb(AsO_3)_2$, which can be prepared by mixing As_2O_5 and PbO or Pb_3O_4 in correct proportions and fusing. The compound melts at a low temperature and forms a thin liquid. When cooled slowly and undisturbed, it forms at a dark red heat a transparent brittle glass. When the glass is broken and heated until semi-liquid, it becomes crystalline. The crystals appear to be hexagonal, are bluish, and have a specific gravity of 6.42. The compound is decomposed by water, the glassy form more quickly than the crystalline.

[1] *Zeit. anorg. Chem.*, **93**, 213 (1915); abstract, *Eng. Min. Jour.*, **102**, 876 (1916).
[2] *Jour. Amer. Chem. Soc.*, **38**, 2014 (1916).
[3] *Op. cit.*, 2027 and 2366.

Lead Ores

Purchasing Lead Ores.—A *Bulletin*, No. 39, dealing with "The Selling of Lead and Zinc" by H. J. Stander has been published by the Bureau of Mines of the University of Arizona, Tucson, 1916–17.

Smelting Practice

Samuel James, the noted lead metallurgist, died at Northport, Wash., on Nov. 25, 1916. Since his graduation at the Massachusetts Institute of Technology in 1876 he has been almost wholly connected with lead smelting. At his death he occupied the position of Manager of the lead smeltery of the Northport Smelting & Refining Co.

Smelting in the Ore-Hearth.—Chain screens[1] consisting of a number of strands of steel chains suspended close together from a bar so as to form a curtain similar to a Japanese screen have been suspended in front of the Newnam ore-hearths at Collinsville, Ill. They have been found very serviceable in protecting the workman from the heat.

Lead Smelting Practice in the United States.—In an extended paper A. S. Dwight[2] discusses the present practice of lead smelting. The main advances made have been in the blast-roasting of material that is to be smelted, and in the mechanical preparation of furnace-charges. The result of this has been improved furnace-work, better metal recovery, an economy in labor, and thereby cheaper production.

Blast-roasting is carried on in the H. & H. pot or the D.-L. machine; the sulphur content of the charge for either does not exceed 16 or 18 per cent. Pyritic ore is usually rough-roasted in a mechanical furnace; the Wedge type is taking the place of the older Godfrey; other sulphides are diluted with low-sulphur materials. An illustrated description of the combination of Wedge and D.-L. furnaces at the Bunker Hill smeltery, Kellogg, Idaho, shows one Wedge multiple-hearth furnace 21 ft. 6 in. in diam. and 22 ft. 11½ in. high, and four D.-L. machines each with an effective hearth area of 42 by 264 in. rated at 100 tons capacity, but treating actually 200 tons in many cases. The use of two D.-L. machines for rough-roasting and sinter-roasting, started at Port Pirie, N. S. W., in 1908, has been adopted recently at some American plants. In connection with the H. & H. pot, the D.-L. machine serves as rough-roaster; the product is crushed to ½-in., mixed with about 16 per cent. limestone of the same size, and finished in an H. & H. pot. The sulphur-content of the sinter with both methods of working ranges from 2 to perhaps 5 per cent. The practice of overburdening the D.-L. machine, started at Tooele, is referred to on page 466.

[1] H. H. Wiegand, *Jour. Ind. Eng. Chem.*, **8**, 836 (1916).
[2] *Eng. Min. Jour.*, **102**, 671–677 (1916).

A rectangular blast furnace is in use universally. It is from 42 to 44 in. wide and up to 18 ft. long at the tuyère-level; the working height ranges from 14 to 18 ft.; the shaft is water-jacketed, the jackets extending with new furnaces from the top of the crucible to the feed-floor; the crucible has an Arents siphon-tap, and a water-jacketed slag-tap. Slag and matte flow into a single removable forehearth, or better into two in series, for separation of matte from slag, the former to be tapped periodically and the latter to overflow continuously into large waste-slag cars which are hauled by electric or steam locomotives to the dump and poured. Charges are dropped from a Williams car onto a Dwight spreader, both of which have been more or less changed from their original designs. The gases are withdrawn from the top or side of the furnace; in the former case a furnace has a high top extending above the feed-floor and a down-take; in the latter the top is level with the feed-floor, the gases being withdrawn beneath it. The author gives a drawing and a description of one of the four blast furnaces of the Northport smeltery. A furnace is 42 by 192 in. at the tuyère-level. It has a working height of 18 ft. and a high top. It is water-jacketed throughout; the lower jackets have a bosh and the upper are vertical; there are twelve 4-in. tuyères on a side. The plant treats mainly Idaho galena concentrates which are treated in D.-L. machines. Details of collecting materials and making up blast-roasting mixtures are given. The charges contain 70 per cent. D.-L. sinter. A furnace treats 250 tons charge in 24 hr., or 4.5 tons per sq. ft. hearth area, with an amount of coke equivalent to 10 to 11 per cent. fixed carbon, and a blast pressure of 30 to 40 oz. per sq. in. The lead content of the charge is about 25 per cent. and the S about 3 per cent.; the matte-fall is 7 per cent., the matte assaying 10 to 12 per cent. Pb; the slags assay 0.5 per cent. Pb. The author in conclusion discusses briefly the work of the Newnam ore-hearth. His remarks have called forth some discussion.[1]

Smelting at Herculaneum, Mo.—Some of the smelting data of this plant printed in the annual report for 1915 are given in the *Engineering and Mining Journal*, **101**, 985 (1916).

Selby Lead Smelter.[2]—The plant of the Selby Smelting & Lead Co. is situated near Vallejo Junction, 29 miles east of San Francisco on the strait of Carquinez. It was erected in 1884. The characteristic of the plant is that it treats materials running very high in silver and gold; in fact, its daily production of gold is larger than that of any smeltery of the country.

The shipments of high-grade ores and intermediary products, usually in small parcels, require careful sampling and assaying. Sulphides are collected in two bins and fed mechanically in quantities adapted to form

[1] *Eng. Min. Jour.*, **102**, 948, 1026 (Garlichs, Dwight.), 1027 (Choate) (1916).
[2] T. A. Rickard, *Min. Sci. Press*, **112**, 505 (1916).

a correct mixture for 42-in. Dwight-Lloyd sintering machines each of which treats from 90 to 150 tons charge in 24 hr. The gases from the machines go to a bag-house. Blast-roasted and other ores are smelted in blast furnaces; they are 36 by 144 in. at tuyères, have a working height of 14 ft. and eight 4-in. tuyères on a side. A furnace treats in 24 hr. from 180 to 240 tons charge with from 12 to 13 per cent. coke (= 9.5 per cent. C) and a blast pressure of from 35 to 40 oz. per sq. in. The slag aimed for is SiO_2, 26; FeO, 38; CaO, 17; Al_2O_3, 7; ZnO, 6 per cent. Slag and matte are tapped into a forehearth 6 by 6 ft. and 2.5 ft. deep; the waste slag overflows into pots of 23 cu. ft. capacity holding 2.5 tons; the matte is tapped into Kilker pans; the lead bullion is cast from a collecting pot into bars weighing 90 lb. Slag- and matte-taps and lead-well are covered with hoods connected with fans delivering into the main flue connected with the bag-house. The matte is roasted and concentrated to 40 per cent. Cu and shipped to Omaha, Neb. The lead bullion with 150 oz. Ag and 7 oz. Au per ton is desilverized by the Parkes process in the usual way. In melting the lead bullion in the softening furnace, the temperature is held as closely as possible to 376° C.; in the kettles the temperature of the lead is held at 450° C. when the zinc is to be melted and stirred in. The zinc crust from the Howard press assays 3000 to 3500 oz. doré per ton. The desilverized lead is siphoned into a refining furnace of 70 tons capacity and freed from the 0.5 per cent. zinc it contains; the refined lead is tapped into a merchant kettle holding 60 tons of lead and siphoned from this into moulds placed in a three-quarters circle. The zinc crust is distilled in graphite retorts. The rich lead, with from 4000 to 6000 oz. doré per ton, is cupelled. The resulting doré silver is parted with sulphuric acid in an exceptionally short time; metallic copper is used to decompose Ag_2SO_4. The $CuSO_4$ is crystallized and the crystals are shipped as blue vitriol in barrels holding 400 lb. Small crystals are sold in bulk to be used for making solutions for spraying. The gold is cast into bars 12 by 5 by 3 in. weighing 1700 to 1800 oz.; the silver is melted in charges of 70,000 to 80,000 oz. and cast.

Smelting at Tooele.[1]—At these works most ores are blast-roasted in Dwight-Lloyd machines before they are smelted in the blast furnace. The lead bullion produced is desilverized at East Chicago, Ind.;[2] the matte is converted without the use of siliceous flux;[3] the flue dust, caught in Cottrell precipitators and filter-bags, goes to the sintering machines.

The blast-roasting division contains 10 Dwight-Lloyd machines 42 by 264 in. When installed, the pallet-travel was 13 in. per min., the tonnage of a machine from 90 to 120 tons; the sulphur-content of the

[1] Anon., *Eng. Min. Jour.*, **102,** 1100 (1916); see also Mineral Industry, **22,** 460 (1913).
[2] Mineral Industry, **23,** 495 (1914).
[3] Mineral Industry, **23,** 487 (1914).

charge was 14.6 per cent. and of the sinter 5.2 per cent. Increasing the pallet-travel to 18 in. per min. gave bad results, but raising it to the present speed, 27 in. per min., proved satisfactory. The daily tonnage is 223 tons with a sulphur-content of charge of 11 8 per cent., and of sinter, 3.18 per cent.; the product contains 18.24 per cent. of material smaller than ½ in. with 7 per cent. S which is removed by passing the sinter over a grizzly. This granular material is added to the blast-roasting charge, and assists in keeping it porous.

Smelting is carried on in five blast furnaces 54 by 180 in. at tuyères with twelve 4-in. tuyères on a side and one at the back. The shaft is water-jacketed with two tiers of jackets, the lower being inclined outward, the upper vertical. The height from feed-floor to tuyères is 24 ft. 8 in. (Drawing of furnace, *op. cit.*, 660.) The use of the upper jackets, while causing a loss in heat, has effected a saving on account of the smaller amount of time and labor required in barring down and in repairing brickwork. The use of one 4-in. end tuyère with the two adjoining tuyères reduced to 2 in. by bushings has done away with crusting at the back of the furnace. A furnace puts through in 24 hr. about 300 tons of charge. No slag shells have been added to the charge since 1915. Analyses of slag and of slag shells are given in Table II.

TABLE II.—ANALYSES OF SLAG AND SLAG SHELLS AT TOOELE LEAD SMELTERY

	Pb, Per Cent.	Cu, Per Cent.	Ag, Ounces per Ton.	Au, Ounces per Ton.
Original slag	1.1	0.28	0.31	Trace
Slag shells	1.4	0.62	0.70	Trace
Original slag	0.7	0.20	0.38	0.005
Slag shells	1.2	0.39	0.85	0.005

Controlled large-scale tests had shown that, as long as a furnace had good settling facilities, by using two forehearths in series to prevent pellets of matte from being carried over by the waste slag, the recovery of values by re-smelting did not pay. With the removal of shells from the charge, the percentage of coke required dropped from 12.92 to 10.76 per cent. An average analysis of the slag overflowing from the second of two forehearths shows: Pb, 1.17; Cu, 0.23 per cent.; Ag 0.37, and Au 0.001 oz. per ton; SiO_2, 30.93; FeO+MnO, 38.87; CaO, 15.22; ZnO, 7.93 per cent.

The Bunker Hill & Sullivan Mining & Concentrating Co.—This company is erecting a new smelting and refining plant at Kellogg, Idaho.[1] The ores treated will be galena and sulphide concentrates. There are provided storage-bins from which the ores are transferred by belt con-

[1] Editor, *Eng. Min. Jour.*, **101,** 868 (1916) general plan; Editor, *Eng. Min. Jour.*, **102,** 658 (1916), drawing of blast furnace; A. S. Dwight, *ibid.*, 674, drawing and description of roasting division.

veyors to the sampling mill which is provided with Vezin machines and has a capacity of 50 tons per hr. The sampled ores go by belt conveyors to the charge-bins of the Wedge multiple-hearth roasting furnace and the four Dwight-Lloyd straight-line sintering machines. Roasted and blast-roasted ores are returned to the charge bins. The Wedge furnace is 21 ft. 6 in. in diam. and 22 ft. 11½ in. high; the Dwight-Lloyd machines have pallets 42 in. wide. From the charge-bins which are provided with scale-hoppers the materials are drawn and weighed into charge-cars which are hauled by electric locomotives to the feed-floor and emptied into furnaces. There are to be three blast furnaces, 48 by 180 in. at the tuyères and 80 by 180 in. at the throat with a working height of 14 ft. A furnace has two tiers of water-jackets which taper from throat to crucible; the side-jackets are 3 ft. wide, the end-jackets 2 ft. There are ten 4-in. tuyères on a side, 18 in. center to center, or two to each jacket. The crucible is 2 ft. 3 in. deep; the lead-well is placed toward the front opposite the second jacket. The furnace has a high top which extends above the feed-floor and carries off the gases through a downcomer. The waste slag is collected in steel pots of 130 cu. ft. capacity which, carried by cars, are hauled to the dump by electric locomotives. The liquid lead bullion is transferred by an overhead electric crane to the drossing plant and thence to the refinery, which will use the Parkes process. Gases are to pass through a bag-house and a Cottrell treater. The refinery will contain two softening furnaces, four desilverizing kettles, two refining furnaces, four merchant kettles, and furnaces for working up drosses and skimmings. The silver division will be equipped with six retorts, two concentrating cupelling furnaces and one finishing furnace. The doré silver is to be parted with sulphuric acid, the silver sulphate decomposed with copper, and the resulting copper sulphate converted into blue vitriol for the market. Gold is to be melted in a crucible furnace.

Roasting.—U. Wedge has patented[1] a multiple-hearth mechanical roasting furnace working on the McDougall principle. The circular furnace has seven superposed horizontal annular stationary hearths built into the side-wall, and seven similar hearths firmly connected with a hollow rotating vertical shaft. The revolving hearths have rabbles on their under sides which move the ore from the feed to the discharge.

Hall Process.—A short paper on the process already discussed in these reviews[2] has been written by H. F. Wierum.[3]

Blast-Roasting.—F. Meyer has patented[4] a down-draft wheel-shaped mechanical blast-roasting furnace which consists of a horizontal annular

[1] U. S. Patent No. 1,159,141, Nov. 2, 1915.
[2] Mineral Industry, **23**, 477 (1914).
[3] *Trans. Can. Min. Inst.*, **18**, 134 (1915).
[4] U. S. Patent No. 1,166,142, Dec. 28, 1915, assigned to Dwight-Lloyd Metallurgical Co., of New York; *Eng. Min. Jour.*, **101**, 526 (1916); *Met. Chem. Eng.*, **14**, 282 (1916).

grate carried by radial pipes ending in a revolving vertical shaft connected with an exhaust. The grate is divided into sections by partitions; beneath each section is a hopper to receive the fines falling through. The ore, fed from a hopper, passes under an igniter, and travels in a horizontal plane during the down-draft blast-roast until it meets a plow which removes the sinter-cake. The suction pipes are automatically closed and opened during certain parts of the travel.

Austin Burner.—The ore-bed of the D.-L. machine was originally ignited from a suspended fireplace using bituminous coal; later gasoline served for this purpose; at present oil residues are generally used. The burner of J. F. Austin[1] has superseded most other forms. It consists of a suspended horizontal arched chamber of refractory material open at the bottom and one end, and closed at the other; the open end has an atomizing oil burner.

Several patents have been granted to A. S. Dwight[2] for a combination of the D.-L. sintering machine and an oil-fired reverberatory smelting furnace.

Double-Roast.—A paper[3] discusses the practice of double-roasting at East Helena, Mont. The operations are: (1) blast-roasting sulphide lead ores in D.-L. machines which are run at a great speed so as to treat 250 tons charge in 24 hr.; they furnish an imperfect product with 6 to 7 per cent. S; and (2) crushing this material to ½ in., mixing it with 16 to 17 per cent. limestone of the same size and finishing the blast-roast in an H. & H. pot which reduces the S-content to from 1 to 2 per cent. The data given in the paper correspond only in part with the actual facts.

Lutes and Cements.—A paper by S. S. Sadtler[4] on lutes and cements is of general interest to all metallurgists. It covers materials which are water- and acid-proof and resist chlorine; it discusses plaster of Paris and marine glue, gasket compositions, cements for machinery, leather, iron, crucibles, magnesia mixtures, and oxychloride cements.

Blast-Furnace Tuyères.—Given a certain volume of air which is to be blown into a furnace per minute, the question of the diameter and with it the number of tuyères that is to be used has not been definitely answered. It is generally held that small tuyères have a greater penetrating power than large. With iron blast furnaces preference has been given to a large diameter; in lead smelting the trend is in the same direction. A. W. Tournay-Hide[5] discusses the experience had at the Cockel Creek Lead Works, N. S. W. With a volume of air of 63,410 cu. ft. per sec. delivered to the furnace, the pressure in the blast main was 46 oz. per

[1] U. S. Patent No. 1,179,390, Apr. 18, 1916; *Min. Eng. World*, **45**, 136 (1916).
[2] U. S. Patents Nos. 1,169,069–139–384, Jan. 18, 25, 1916.
[3] Anon., *Min. Sci. Press*, **112**, 672 (1916).
[4] *Met. Chem. Eng.*, **14**, 197 (1916).
[5] Engineering Assoc. N. S. W.; *Min. Eng. Review*, June 15, 1916; *Eng. Min. Jour.*, **102**, 392 (1916).

sq. in., that in the 3-in. tuyère from 41 to 42 oz., and that 6 in. beyond the tuyère in the furnace from 35 to 41 oz. With the tuyères reduced to 2 in. the pressure in the mains had to be raised to 51 oz. to obtain the same volume of air. It was found that a difference of from 3 to 5 oz. per sq. in. between pressure in tuyère and in furnace is sufficient to force the necessary quantity of air into the furnace; also that an increase of normal pressure of from 45 oz. to 55 oz. in the main caused an increase of from 0.5 to 1.0 oz. effective difference of pressure in the pipe for forcing air in the furnace. Therefore, large diameters of tuyères are preferable to small. In most modern American furnaces the usual diameter of 3 in. has been increased to 4 and 4.5 in.

R. H. Vail[1] gives drawings of the tuyères in common use to-day with the leading copper and lead blast furnaces. With all furnaces a cast-iron elbow is attached to the jackets in some way to form an air-tight joint; the questions of avoiding other air-leakages, of providing slag-escapes and of removing chilled slag is solved in a variety of ways.

Preparation and Mechanical Feeding of Blast-Furnace Charge.—The older methods of bedding ores characteristic for hand-feeding lead blast furnaces have been gradually falling into disuse with the advent of mechanical feeding. Bedding ores was first abandoned at the smeltery of Tooele, Utah; it has been given up at Trail, B. C.; the latest, and probably the most satisfactory method of preparing charges and delivering them to the feed floor is the one devised by L. D. Anderson[2] for the lead plant at Midvale, Utah. The leading facts have already been given in these reviews.[3]

Slags.—A. Selivanoff[4] has examined the freezing-point curve of ferro-calcic singulo-silicates. He found a chemical compound $2Fe_2SiO_4$.-$3Ca_2SiO_4$ freezing at about 1250° C., one eutectic with about 33 mol. per cent. of Ca_2SiO_4 freezing at about 1160° C., and another with about 65 mol. per cent. Ca_2SiO_4 freezing at about 1210° C. The horizontal eutectic lines do not extend to the vertical denoting the chemical compound. The diagram shows slight solid solutions on both ends of the field and transformations in the solidified mixtures.

Slag Shells.[5]—Until recently the common practice of all lead smelteries has been to return slag shells to the blast-furnace charges, as they keep the charge open, are helpful in smelting, and give up values which would otherwise be lost. With 70 per cent. of the modern charge made up of blast-roasted material, it is not necessary to keep the charge open. Such a charge requires no outside assistance to smelt satisfactorily. With proper

[1] *Eng. Min. Jour.*, **102**, 639 (1916).
[2] *Eng. Min. Jour.*, **101**, 885 (1916).
[3] MINERAL INDUSTRY, **24**, 465 (1915).
[4] *Rev. Soc. Russe de Métallurgie*, **2**, 328 (1915), through *Rev. Mét. Extr.*, **12**, 309 (1915).
[5] C. Pigott, *Eng. Min. Jour.*, **102**, 626 (1916).

settling facilities shots of metal or pellets of matte can be settled completely from a well-composed slag. Experiment has shown that values which can not be recovered by settling are not extracted by re-smelting. Hence the three leading reasons favorable to re-smelting slag shells have ceased to be of importance. There is, however, a great disadvantage in the practice, as the zinc oxide and sulphide contained in the slag shells are returned to the charge and make the smelting less favorable. It has been held that smelting slag did not require any additional fuel; with the common practice of using as little coke as is possible, it has been found that omitting slag reduced the percentage of coke required by 1 per cent. Further, the space in the furnace occupied by the former 15 per cent. of foul slag is available for ore-charge, hence the smelting capacity of the furnace is increased by the omission of this ballast.

Waste Slag.—A method of using waste slag from the blast furnace by casting into the form of reinforced launders from 1 to 2 in. in thickness has been developed by W. A. Leddell[1] and put into operation at Morenzi, Ariz. The slag is poured into open cast-iron moulds placed upright. The mould is covered with a plate having an in-pour. Before casting, two pieces of 26- or 28-gauge wire poultry netting with 1-in. or 1.5-in. hexagon openings are placed along the sides. When the slag has chilled slightly the mould is removed, the slag-casting laid on the ground, and covered with a thin layer of non-conducting material, such as sand or lime; on top of the first casting is placed a second which receives its layer of sand or lime. In this manner the castings are piled, and, cooling slowly, annealed. These launders cost about 12 cts. per ft. compared with 90 cts. for cast iron; their life in a concentrating plant is from three to four times as long; acid water has no effect on them.

Matte.—The blast-roasting of matte has always been a source of trouble. A new departure has been made at Herculaneum, Mo.[2] The granulated matte, with particles not exceeding ½ in. in size, is mixed with an equal volume of limestone (dolomite) crushed to ½ in. or concentrate tailing (dolomite), thoroughly wetted and blast-roasted on a D.-L. machine run at a speed to treat in 24 hr. about 75 tons charge. There results a well-sintered product with from 4 to 4.5 per cent. S. An analysis gave Pb, 10.39, Cu, 1.64, insol., 3.03, SiO_2, 2.35, FeO, 44.24, CaO, 16.05, MgO, 9.28, S, 4.70, Zn, 3.59 per cent.

The desilverization of matte by means of lead is known to be incomplete. W. Mostowitsch[3] has shown by laboratory experiments that the extraction of Au and Ag from matte increases with the amount of Pb in the charge; that the recovery of Au is complete with Pb equal to 80

[1] *Eng. Min. Jour.*, **102**, 644 (1916).
[2] Editor, *Eng. Min. Jour.*, **101**, 943 (1916); Private Notes, July, 1916.
[3] *Met. Chem. Eng.*, **45**, 703 (1916).

per cent. of the weight of the matte; and that matte gives up only 72 per cent. of Ag with 100 per cent. of Pb. The explanation is sought in the reaction $2Ag_2S + 2Pb = Ag_2Pb + Ag_2S.PbS$, which conforms to the general principle laid down by Schütz[1] that the decomposition of a metallic sulphide by a metal is never complete.

U. Wedge has patented[2] a process for treating lead matte.

N. V. Hybinette has patented[3] a process for freeing leady matte from lead. The matte is to flow through a series of furnaces in which it comes into contact with the metallic copper which is to precipitate the lead. Arriving at the last furnace the matte is to have been freed from lead and be ready for converting; at the same time the lead carrying the precious metals is to have flowed in the opposite direction, and to be tapped from the first furnace.

Condensation.—U. Wedge has patented[4] a dust-chamber which embodies novel features. Several oblong chambers are placed in a row; between a chamber and its neighbor is a vertical flue which collects dislodged dust. A chamber is filled with a number of superposed gable-shaped metal plates; ridge-poles and supports at the lower ends of the plates determine the distances between the several plates. Suspension rods pass through the ridge-poles and extend beyond the chambers. Dust- and fume-laden gases travel through a chamber between the plates and drop suspended particles. The dust that has collected on the plates is dislodged by striking the extensions of the suspension rods; gliding down the plates it drops into the vertical collecting flues whence it is removed periodically.

Bag-house at Midvale.—The new bag-house of the U. S. Smelting, Refining & Mining Co. at Midvale, Utah,[5] has some novel features which are of interest. It is intended to filter per minute 60,000 cu. ft. of gas at 65° C.; a No. 14 Sirocco fan draws the gases from the furnaces and delivers them into the cellar of the bag-house. There are five bays, each with 240 thimbles 11 in. in diam. and 10 in. high, or 1200 in all. The bags are 34 ft. long and are made of 42-in. canvas, double-sewed with 1-in. laps; they represent a filtering surface of 324,000 sq. ft. through which the gases travel at a speed of 1 ft. in 5 min. The filtering chamber, 21 ft. by 139 ft. 5 in. and 33 ft. 6 in. high, is of structural steel with an inner covering of ⅛-in. asbestos board, and an outer of corrugated iron. The inner covering prevents the condensation of moisture and thereby counteracts the corrosion of the bags.

The outlet-flue is placed near the top; on one side it has baffle plates

[1] Mineral Industry, **16**, 662 (1907).
[2] U. S. Patent No. 1,198,988, Sept. 19, 1916.
[3] U. S. Patent No. 1,175,266, Mar. 14, 1916.
[4] U. S. Patent No. 1,165,351, Dec. 21, 1915, *Eng. Min. Jour.*, **101**, 646 (1916).
[5] L. S. Austin, *Min. Sci. Press*, **112**, 746 (1916).

to regulate the travel of the gases. Shaking of bags has been replaced by the alternate pressure and vacuum system; acid gases are neutralized by means of finely-ground slaked lime. The paper gives drawings of the bag-house and of the lime feeder.

A. D. Bryant has patented[1] a device for shaking suspended filter bags by means of compressed air. When a set of bags is to be shaken, the gas current is first shut off, which causes the bags to collapse; compressed air is then admitted within the individual bags through nozzles which are placed at right angles to one another at the different points. Successive puffs of air locally distend the bags and shake them; by having the air act alternately at different points, a vibratory movement can be imparted to the bags.

Smelter Smoke.—The injury of smelter smoke to vegetation has been discussed in a general way by J. P. Mitchell.[2] The harmful constituents of the smoke are lead, arsenic, sulphur trioxide and sulphur dioxide. The deposition of lead and arsenic does not injure vegetation but poisons animal life; sulphur trioxide destroys the surface of plant tissue, turning it brown or black; sulphur dioxide has the most injurious effect upon vegetation in that it is absorbed by and combines chemically with some constituent of the plant, remains fixed in the tissue and acts as a slow poison which eventually kills the plant.

In studying the effects of smelter smoke, potted plants in small cabinets were first exposed to its action; then came plants in larger pots or boxes in relatively large houses; and finally field conditions were studied by means of portable chambers placed over plants growing in the open. The sulphur-content of a plant forms the chemical evidence of the effect sulphur dioxide has had upon it, provided, however, that the sulphur-content of a similar plant grown under similar conditions in a region not exposed to sulphur dioxide is known, and that the sulphur-contents of the exposed and unexposed soils have been determined.[3]

Thiogen Process.—In this process[4] the SO_2 from smelter gases is absorbed in a gossage tower by a "mother liquor"; BaS is added to the collected liquor, which precipitates $Ba_2S_2O_3$, $BaSO_3$ and S. The precipitate is filtered, giving mother liquor and residue; the residue is heated in a closed vessel, gives off the elemental S and one-half of that of the $Ba_2S_2O_3$, leaving a residue of $BaSO_3$ with some $BaSO_4$ which is reduced to BaS to be used again for precipitation. The reduction of $BaSO_4$ to BaS has been investigated for the Bureau of Mines by A. E. Wells.[5] He

[1] U. S. Patent No. 1,163,318, Dec. 7, 1915.
[2] *Trans. Amer. Inst. Chem. Eng.*, Aug. 27, 1915; through *Jour. Ind. Eng. Chem.*, **8**, 175 (1916).
[3] NOTE.—The smelteries near Salt Lake City and Anaconda are growing diversified crops near thei plant and studying the effects of smoke.
[4] MINERAL INDUSTRY, **20**, 491 (1911); **21**, 559 (1912); **22**, 474 (1913); **23**, 480 (1914).
[5] *Jour. Ind. Eng. Chem.*, **8**, 770 (1916).

finds that on the whole the reduction of $BaSO_4$ to BaS is insufficient to form the basis of a cyclic process.

Cottrell Process.—The recent progress in electric smoke precipitation has been reviewed before the second Pan American Scientific Congress by F. G. Cottrell.[1] He gives the history of the process, discusses its theory, and shows the various applications which have been made in the collection of fume and dust in metallurgical and other industrial plants of Oregon, California, Arizona, Utah, Colorado, Pennsylvania, New York, Conneticut and British Columbia. The paper, to which the reader is referred for details, contains a bibliography.

A similar paper has been published by W. A. Schmidt.[2]

Smelting Mixed Sulphide Ores.—J. H. Klepinger, M. W. Krejci and C. R. Kuzell have patented a process[3] in which they propose to blow a powdered mixture of oxides of lead, copper and zinc, of coal, and of flux into a reverberatory furnace in a manner similar to that of firing with fuel dust, and burning the mixture with the air necessary to form a reducing flame, when ore and flux are to smelt and form metal and slag to be withdrawn from separate levels.

Leaching Lead-Zinc Ore.—R. S. Handy has patented[4] a process for leaching sulphide lead-zinc ores, which appears to be rather complicated.

C. C. Titus and W. J. Barenscheer have patented[5] a wet process for the treatment of mixed sulphide silver- and gold-bearing ores containing lead, copper and zinc.

The lixiviation of low-grade carbonate lead ores which can not be enriched by mechanical concentration has been investigated at the research laboratory of the Bureau of Mines at Salt Lake City by D. A. Lyon, O. C. Ralston, J. F. Cullen, and C. E. Sims.[6] Their process is discussed by H. R. Ellis and S. A. Ionides[7] and M. R. Thompson.[8] Carbonate lead ores contain lead in the form of $PbSO_4$ and $PbCO_3$; acidulation with H_2SO_4 converts $PbCO_3$ into $PbSO_4$. Sulphide lead ores subjected to a slow oxidizing roast give from 75 to 99 per cent. $PbSO_4$, and 25 to 1 per cent. PbO; the latter is converted into $PbSO_4$ with H_2SO_4. Both $PbSO_4$ and $PbCl_2$ are readily soluble in saturated brine. From suitable ores as much as 95 per cent. of the lead has been extracted. From the solution loose spongy lead is precipitated electrolytically and drops off from the cathode, is removed mechanically from the vat, melted, and cast into bars. With an iron anode, which goes into solution, it has been found possible

[1] *Eng. Min. Jour.*, **101**, 385 (1916).
[2] *Trans. Can. Min. Inst.*, **18**, 110 (1915).
[3] U. S. Patent No. 1,160,621, Nov. 16, 1915.
[4] U. S. Patent No. 1,185,902, June 6, 1916.
[5] U. S. Patent No. 1,173,467, Feb. 29, 1916.
[6] *Met. Chem. Eng.*, **14**, 31, 176 (1916); **15**, 410 (1916).
[7] *Op. cit.* **14**, 122, 176 (1916).
[8] *Op. cit.* **15**, 614 (1916).

to use a current density of 90 amp. per sq. ft. cathode area with a drop in potential of only 0.5 volt. Under these conditions 70 lb. lead has been deposited per kw.-hr. in the form of a sponge with only 1 per cent. iron remaining in the electrolyte in a cyclic run, the rest having been hydrolyzed or fallen out of solution as a basic chloride. Soluble zinc salts accumulate in the electrolyte to the extent of 1 per cent.; Na_2SO_4 is only slightly soluble in saturated brine; the small amount which goes into solution increases the dissolving power for $PbSO_4$. Silver follows the lead. Insoluble anodes have given poor results. The plant proposed has cast-iron electrodes arranged in series in a tank with V-shaped bottom containing a screw-conveyor to remove the spongy lead. The paper gives an outline of plant and an estimate of cost of treatment as $33 per ton of lead with a plant producing 10 tons per day.

Desilverization

Betts Process.—The Betts process at Trail, B. C., has undergone many changes since it was installed. At present[1] the cathode starter sheets, 39 by 27 in. and 1/32 in. thick, are prepared by tilting a hinged 6-in. trough and pouring its content of liquid lead on an inclined cast-iron plate, trimming the rough edges, and wrapping one end around a bright copper busbar. In 8 hr. 4000 sheets are finished. The anodes, of similar dimensions to the cathodes, weigh from 312 to 320 lb. Two cathodes are pulled for each anode, which then has lost from 80 to 85 per cent. of its weight. The 408 tanks of the plant are of cement concrete, covered with P. & B. paint and coated with asphalt; they treat 100 tons of lead bullion per day. The electrolyte contains 10 per cent. H_2SiF_6 and 5 per cent. $PbSiF_6$; fresh acid has to be added once a week. The anode mud with that from the electrolytic copper refinery is dried and partly roasted in pan-cars which are placed in the flues conveying the hot gases of doré furnaces to the dust-chamber and stack. The oxidized slime is melted without fluxes in a reverberatory furnace having a hearth lined with magnesite brick. The slag is skimmed, and fresh oxide is charged until the hearth is filled with doré silver 970 fine which is cast into bars and parted with sulphuric acid. The electrolytic lead for December, 1916, averaged Au 0.0027 and Ag 0.6126 oz. per ton; Cu 0.0026, Fe 0.0068, and Sb 0.0075 per cent.

Miller Casting Machine.—At the Trail plant of the Consolidated Mining & Smelting Co., of Canada, J. F. Miller[2] has introduced a compact casting machine which handles 12 tons lead per hr. with 3 men. The

[1] T. A. Rickard, *Min. Sci. Press*, **113**, 941 (1916).
[2] U. S. Patent No. 1,157,794, Oct. 26, 1915; *Eng. Min. Jour.*, **102**, 662 (1916).

leading parts are; a vertical wheel with water-jacketed moulds placed across the spokes; a stationary curved water-jacket on the feed side which extends above the center of the wheel and fits snugly the periphery of the revolving mould-wheel; a feed-pipe in the stationary jacket to deliver the lead into the moulds as they pass by underneath; and a shield on the delivery side to break the drop of the discharged bars as they fall onto a car or conveyor. Each mould has a recess in the lip for the escape of air into the next mould and for receiving after the escape of the air a small amount of lead to serve as a sample which is discharged automatically when the bar drops from the mould. The lead is delivered to the feed-pipe from a kettle by a Miller pump, the excess flowing back into the kettle through a return-pipe. The bars are free from rough edges, shrink-holes and dross, and have a very uniform weight.

MAGNESITE

BY SAMUEL H. DOLBEAR

Magnesite is usually defined as the normal carbonate of magnesia, composed, when pure, of magnesium oxide 47.6 per cent., and carbon dioxide 52.4 per cent. Mineralogically this definition is correct, but magnesite subjected to heat loses its carbon dioxide, and the residual magnesium oxide is also designated as "magnesite." The use of the word has become too general to limit its application alone to the carbonate. Furthermore, the word "magnesite" is not used generally in describing artificially prepared magnesium carbonate.

Vein Deposits.—Magnesium forms with silica a long list of silicates. Very few of these occurring in nature are simple silicates of magnesium, for they usually contain iron, alumina, lime and sometimes other elements in varying formulæ, as for example hypersthene, diopside, and the more complex augites.

The ease with which magnesium silicates are broken down when brought in contact with carbonic acid and water has been demonstrated in the laboratory. In the case of the alteration of olivine the reaction is represented by the equation:

$$2Mg_2SiO_4 + 2H_2O + CO_2 = H_4Mg_4Si_2O_3 + MgCO_3$$

and similarly in enstatite,

$$4MgSiO_3 + H_2O + CO_2 = H_2Mg_3(SiO_3)_4 + MgCO_3.$$

In each case magnesite ($MgCO_3$) is one of the products, while it will be seen that the residual materials possess chemical formulæ different from one another. This residual material is represented in nature principally by serpentine, but sometimes by such substances as talc and chlorite. It is noted that water plays an important part in these reactions, the residual material usually becoming hydrous. These reactions, however, appear to be incomplete, and it is logical to conclude that all of the magnesium present in the original rock—olivine, enstatite, etc.—may be converted to magnesium carbonate if the conditions resulting in the incomplete change persist. Then reaction (1) below would be followed by reaction (2), the conversion of all magnesium present to $MgCO_3$ would be accomplished, while water and silica would be set free, so:

$$(1)\ 4MgSiO_3 + H_2O + CO_2 = MgCO_3 + H_2Mg_3(SiO_3)_4.$$
$$(2)\ H_2Mg_3(SiO_3)_4 + 3CO_2 = 3MgCO_3 + H_2O + 4SiO_2.$$

This would then account for the free silica in magnesite deposits, and justify the supposition that deposits in rocks that are greatly altered are more likely to contain high proportions of silica than those in less altered areas.

Carbonic Acid.—Several sources of carbonic acid are possible:

1. Atmospheric carbonic acid.
2. Organic—arising from oxidizing organic matter.
3. Occluded gases.
4. Deep deposits of calcium carbonate.

Deposition of Magnesite.—The presence of CO_2 in great excess would increase the solubility of $MgCO_3$, and this would be deposited when the solution yielded its excess CO_2 through freedom from pressure, cooling, evaporating, or because a part of the CO_2 would be required to form $MgCO_3$ with the magnesium-silicate rocks with which it would come into contact. Then we would have magnesite replacing the wall rock of veins, and examples of this kind are common. It may be recognized either by the presence of serpentine "horses," or by the gradation of magnesite into the wall-rock, usually without any distinct mark between the two.

We have then two types of deposits resulting from the alteration of magnesium silicates, the true vein deposit and that resulting from replacement. The latter would usually be irregular in form and might be designated as lenticular.

Sedimentary Deposits.—Two of these have been reported in the United States; they are believed to have resulted from the contact of soluble magnesium salts with alkaline carbonates. The most common soluble magnesium compounds found in nature are the chloride and sulphate. The reaction would be represented by:

$$MgSO_4 + Na_2CO_3 = MgCO_3 + Na_2SO_4, \text{ or}$$
$$MgCl_2 + Na_2CO_3 = MgCO_3 + 2NaCl.$$

Sodium carbonate is common in the desert alkaline basins, and it is in these regions that the sedimentary deposits are found. The question, therefore, is not the source of the carbonate radical, as in the case of vein-type deposits, but the source of soluble magnesium compounds. In the Pacific Coast regions there are two examples of this type of deposits, one at Bissel, near Mojave, Cal., and another near St. Thomas, in Nevada. Data regarding magnesium rocks that might act as a source of magnesia in the latter locality are not available. The magnesian series in the Bissel area are represented by talc, actinolite, and similar alteration products of primary basic rocks. The presence of gypsum ($CaSO_4$) and sodium sulphate in this area suggests that the magnesium salt entering into the final reaction to form magnesite was magnesium sulphate.

The sulphuric acid radical undoubtedly has its origin in decomposing pyrite, but it is not at all certain that the alteration of magnesium-silicate rocks was due directly to contact with sulphuric or sulphurous acid in the circulating ground-water. Had this been the case the decomposition would probably have been more complete, and the resulting solution would have contained much iron. Analysis of the Bissel ore does not disclose a large iron content. Four analyses show:

$$Al_2O_3 + Fe_2O_3\text{: 2.46 per cent.; 2.94; 1.40; 0.76.}$$

(Analyses by J. S.Fairchild, U. S. Geological Survey.)

Evidence points to alteration by carbonic acid and the subsequent action of sulphuric acid on magnesium carbonate in solution to form the more soluble magnesium sulphate. This was carried to the playa in solution, and here brought into contact with alkaline carbonates, also in solution, as indicated by the reaction stated above.

Another point leading to the belief that magnesium sulphate rather than magnesium chloride was the salt involved, is the relatively small quantity of lime present. The agencies producing magnesium chloride would probably also have produced calcium chloride, the solubility of which is very high. In the case of sulphates, the calcium salt would be insoluble and a separation afforded from the magnesium sulphate. Analyses for CaO reveal; 4.25 per cent.; 3.36; 1.56; trace. (*Ibid.*)

The recent discovery of dolomite, adjacent to the deposits of sedimentary magnesite at Bissel, can not be explained until further data regarding the occurrence are available. It will probably be found to have originated during a different geological period, and from a source not closely related to that of magnesite.

Deposits of sedimentary magnesite should be examined for soluble alkalines if intended for refractory use, because the presence of such alkalines in quantity would reduce the fusing point of the material.

Hydro-magnesite.—This is a magnesite having the composition $3MgCO_3Mg(OH)_2 + 3H_2O$.

It occurs both in sedimentary and vein deposits, and in the latter is probably a secondary product formed when magnesite has been re-dissolved and re-precipitated by chemical reactions, such as are described in the foregoing paragraphs on sedimentary magnesite. It is usually associated only sparingly with magnesite in veins, although at Red Mountain in Stanislaus County, at Devil's Hole in Alameda County, and in British Columbia it is found separately in quantity.

Production

The production of magnesite in the United States was several times greater in 1916 than in any previous year. As in previous years, the output was limited exclusively to California. The amount mined and shipped is estimated by the U. S. Geological Survey to be 154,000 tons, of which 74,000 tons was produced in Tulare County, largely from mines in the vicinity of Porterville. Irregular shipments were made from Greece to the United States during the year, but the deliveries were dependent upon available bottoms and other influences governed by the war.

IMPORTS OF MAGNESITE CALCINED, NOT PURIFIED
(Fiscal years ending June 30, in short tons)

Country.	1912.	1913.	1914.	1915.	1916
Europe:					
Austria-Hungary	99,104	163,715	134,260	52,086	
Belgium	25		11		
Germany	689	2,412	2,578	722	12
Greece	114	1,605	3,232	4,437	11,413
Denmark			58	103	
Italy				710	
Netherlands	2,410	4,508	4,191	3,554	1,950
Norway	163				22
United Kingdom—					
England	61	1	12	130	
Scotland			1	151	349
North America:					
Canada	234	350	404	948	2,440
Mexico	81				
Other countries	(b)57			(a)508	
Total	102,938	172,591	144,747	63,348	16,186

(a) Venezuela.
(b) British East Indies.

These shipments were made in cargo lots and at times the market was called upon to absorb large quantities of this ore on its receipt. This influenced the demand for California material and for a time during the summer months of 1916, operators who had no contracts for continuous delivery were obliged to close down. Prices ranged widely during the year, starting out at $12 per ton crude, f.o.b. shipping point, and gradually becoming lower until in July and August, ore was offered at as low as $6.50 per ton. The average price of crude during the year was about $8.50 on cars at point of shipment. Calcined material varied in price from $25 to $40 per net ton in bulk, unground, f.o.b. California points. Practically all of the magnesite calcined in California is contracted for in advance, and these contracts were made at $25 to $35 per ton; the higher prices are represented by the sale of small spot tonnages.

THE PRINCIPAL SUPPLIES OF MAGNESITE
(In metric tons)

Year.	Austria-Hungary. (*a*)		Greece.		India. (*d*)	United States. (*d*)
	Crude	Calcined	Crude	Calcined		
1901	....	40,236	20,348	....	(*e*)	4,286
1902	....	53,467	23,020	....	3,597	2,567
1903	....	69,058	28,415	....	838	1,234
1904	....	53,781	9,133	....	1,193	2,585
1905	....	92,359	37,063	....	2,645	3,568
1906	....	87,765	40,584	....	1,861	7,093
1907	452	113,695	55,816	....	188	(*f*) 6,858
1908	212	87,049	63,079	....	7,655	(*f*) 5,994
1909	1,027	125,666	56,797	16,609	199	(*f*) 8,588
1910	341	182,911	18,073	19,982	5,264	(*f*)11,291
1911	77	182,911	86,956	27,530	3,546	(*f*) 8,505
1912	....	171,196	106,338	33,848	15,626	(*f*) 9,534
1913	....	200,947	118,054	40,972	16,468	(*f*) 8,741
1914	....	....	136,701	28,563	1,706	(*f*)10,248
1915	....	....	92,661	18,726	7,570	(*f*)27,669

(*a*) Exports. (*d*) Crude magnesite. (*e*) Not reported. (*f*) U. S. Geol. Surv.

Mine Operation in California. Alameda County.—The only deposit operated in this county was that at Cedar Mountain, which shipped a few carloads of crude ore. The mine is equipped with a reverberatory-type furnace, but this was not used.

Fresno County.—Production in Fresno County was limited to the Piedra district, for which Piedra, a terminal point on the Santa Fe R. R., is the shipping point. The mines are small and much of the ore is low grade.

Kern County.—The Rex Plaster Co. continued to operate its deposit near Bissel, most of the ore being shipped to Los Angeles for calcination, the company's plant being situated at that point. This plant was destroyed by fire in July, 1916. This is the only deposit of sedimentary magnesite known to occur in California. This company also controls a deposit in the Porterville district, adjoining that of the Lindsay Mining Co.

Napa County.—This county has come into prominence by the development of three mines of considerable promise. The oldest of these is the property of the Tulare Mining Co. in Chiles Valley, and has been operated intermittently for a number of years. Situated also in Chiles Valley is the Detert mine. During the past year a good deal of development work was carried on, but no ore has been shipped. The Sweasey mine in Pope Valley was the largest producer in the county. The crude ore was hauled to Zinfandel station, 4 miles from St. Helena, both wagons and trucks being used. Some of the ore was calcined at small kilns on San Francisco Bay, but the bulk of production was sold as crude. The mines in this county are all at distances from railroad ranging from 10 to 16 miles. Whenever rain falls the roads become impassable, and shipments have to be suspended. A small kiln was erected by Sears Cubbage at Rutherford station and a small amount of ore treated.

Early in 1917 five vertical kilns were erected 4500 ft. below the mine, and an aerial tram put into operation between the plant and mine. Coke is used as fuel. The calcined product is hauled to Rutherford, 23 miles distant, for rail shipment.

Riverside County.—The mine at Winchester, formerly operated by the Magnesite Refractory Products Co., was leased and a plant partly erected at the deposit. Careful sorting of the ore is necessary, about 5 tons of waste being removed to recover 1 ton of ore. Operations were later suspended for lack of funds.

Sonoma County.—The Refractory Magnesite Co. erected a stack-type kiln at its mine near Preston, and commenced the production of calcined magnesite during the summer of 1916. Prior to that time the crude ore was shipped to Oakland and calcined at a plant which recovered the carbon dioxide content. The ore is ferruginous, iron being present as the carbonate, which imparts a greenish color to the material when mined. Upon calcination the ore becomes dark brown, due to the reduction of Fe_2CO_3 to FeO.

The Sonoma Magnesite Co. operated its rotary kiln intermittently during the year, and made shipments of the calcined product. Its projected narrow gage road was completed, but its use was prevented by an injunction granted an owner of the land across which the track had been laid. The mine is situated 14 miles from Guerneville, to which point the product was formerly hauled.

The Meecher deposit, 8 miles northeast of Guerneville, was developed during the year, and a road a mile in length nearly completed, but no ore was shipped.

A few carloads were shipped from Cloverdale and Preston, aside from that mined by the Refractory Magnesite Co.

Santa Clara County.—The Western Magnesite Development Co. shipped a large amount of both calcined and crude ore during 1916, its production exceeding that of any former year. The deposits are situated at Red Mountain, 35 miles from Livermore. The material is hauled by auto-trucks.

The Pacific Magnesite Co. developed its deposits, but no material was shipped.

Tulare County.—This county was the scene of intensive development of its magnesite resources, and its yield of both crude and calcined was by far the most important in the State.

The calcining plant at Porterville, construction of which was commenced by the California Magnesite Co., was completed by the American Magnesite Co., and is operated as a custom calciner. Its output, ranging from 60 to 80 tons per day, is shipped to the American Refractories Co's. Illinois and Ohio plants and there made into fire-brick.

The Porterville Magnesite Co. is the largest individual producer in the district, its deposits being situated about 4 miles northeast of Porterville. The 50-ft. rotary-kiln of this company was put into operation, and a new rotary-kiln 125 ft. long and 7 ft. diameter was erected in March, 1917. About 150 men are employed.

The Tulare Mining Co. greatly increased its production during the year, employing two vertical-type kilns for calcination. This company is a subsidiary of the Crown-Willamette Pulp and Paper Co. and most of the output was formerly shipped to the Company's paper mills in Oregon. Its surplus production during the past year was shipped to eastern consumers.

The Lindsay Mining Co. produced about 15,000 tons of crude in 1916. This company built a 5-mile standard-gage extension to the Porterville Northwestern Railroad and improved its property with tramways, bins, and drills, and other equipment. About 70 men are employed. R. D. Adams is manager.

Doyle and Smith developed the Stewart deposit near Zante and shipped several thousand tons of crude.

About 20 deposits were operated during the year, the magnesite mining industry enjoying the most prosperous year in its history.

STATISTICS OF CRUDE MAGNESITE IN THE UNITED STATES
(Tons of 2000 lb.)

Year.	Production. (a)	
	Tons.	Value.
1903	3,744	$10,595
1904	2,850	9,298
1905	3,933	15,221
1906	7,805	23,415
1907	7,561	22,683
1908	6,587	19,761
1909	9,465	37,860
1910	12,443	74,658
1911	9,375	75,000
1912	10,512	84,096
1913	9,632	77,056
1914	11,293	124,223
1915	30,499	274,491
1916 (b)	154,000	1,309,000

(a) U. S. Geol. Surv.
(b) Estimated.

Washington.—Several deposits of magnesite have been discovered in the vicinity of Chewelar, Wash., and development work commenced in

1916. These deposits are quite different in character from those in California. They are regarded as replacement deposits, having been originally laid down as limestones. Later intrusions of basic magnesia rocks resulted in the replacement of calcium carbonate by magnesium carbonate. The theory of one authority that they represent an extreme magnesian phase of dolomite is not justified by the evidence available at the time of the writer's visit (January, 1917), but a careful study of these occurrences was not possible because of heavy snowfall. The deposits have been tilted by intrusions, and they are worked by open-quarry methods, the ore being hauled during the winter in sleds from the quarry to Valley and Chewelar, the distance varying from 8 to 15 miles from the different quarries.

Magnesite is being shipped from five deposits, and others in the district will probably produce during the year.

Greece.—In 1915 the Grecian output of magnesite was 133,858 metric tons of crude. Of this amount 33,641 tons of crude was shipped to the United States, the remainder going to England, France and Netherlands. During 1916 cargoes were landed at American seaboard at irregular intervals. The figures for 1916 will probably not be available for several months.

IMPORTS OF MAGNESITE INTO THE UNITED STATES

	1914.		1915.		1916.	
	Pounds.	Value.	Pounds.	Value.	Pounds.	Value.
Magnesia:						
Calcined (Medicinal)	159,547	$19,342	94,324	$10,462	54,981	$14,659
Carbonate (Medicinal)	46,183	2,527	48,817	2,757	9,202	1,048
Sulphate	13,826,899	53,768	3,560,701	16,050	674,594	4,036
Magnesite:						
Calcined, not purified	243,633,205	1,323,194	53,148,739	392,071	150,689,445	634,447
Crude	26,708,381	54,677	99,527,772	255,140	18,539,704	204,183

Italy.—A magnesite deposit is being worked in Italy that is said to contain over 1,000,000 tons. The analysis of this ore is said to run: magnesium carbonate, 88.11 to 90.03 per cent.; silica, 2.06 to 3.40 per cent.; lime, 2.68 to 3.34 per cent.; and iron oxide, 1.60 to 2.30 per cent. The material is made into refractory brick, and has replaced the magnesite formerly obtained in Greece and elsewhere.[1]

Canada.—Magnesite was quarried and shipped chiefly from Grenville Township, Argenteuil County, Quebec, supplemented by several hundred tons from the Atlin district in British Columbia.

The total shipments in 1916 were 55,413 tons, valued at $563,829, or an average of $10.17 per ton.

[1] *Min. Sci. Press*, Feb. 10, 1917.

In 1915 the shipments were 14,779 tons, valued at $126,584, or an average of $8.56 per ton, and in 1914, 358 tons valued at $2240.

Mexico.—The International Magnesite Co. continued operation of its deposit on Santa Margarita Island in the Gulf of Lower California. Shipments were made by small steamers chartered for the purpose, the ore being landed at San Diego and calcined at the company's plant at Chula Vista, 14 miles south of that city.

The discovery of magnesite on Cedros Island, off the west coast of Mexico, is attracting attention, and the latter deposits may be operated during 1917.

Austria.—Very little information is available regarding operations at the Austrian mines. The American owners of the mines in Austria are themselves able to get only meager accounts of the activities of their Austrian company. It is probable that no accurate data will be available until after the war.

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MANGANESE

By Allison Butts

Manganese is so closely allied with the steel industry that their statistics always have a common trend. Accordingly 1916 was a year of great activity in manganese. Production was greatly stimulated in the United States, Brazil, and other countries. Internal conditions in India, together with the difficulty of making shipments, kept the production there at but little more than half normal. The same is true of the remaining important source of manganese, Russia, only the depression in Russia was much greater. The Russian deposits are said to be the most extensive in the world, and their chief outlet has been through the Dardanelles previous to the war. However, even in Russia and India there was some improvement over the conditions of 1915, though our information as to this can be gathered only from reports and no definite figures are as yet available.

United States

Manganese in the steel industry is used almost entirely in the forms of ferro-manganese and spiegeleisen. Ferro-manganese (77 to 80 per cent. Mn) is used mainly for open-hearth steel, and spiegeleisen (12 to 33 per cent. Mn) mainly for Bessemer steel. Recently, owing both to the greater increase of open-hearth production and the greater difficulty of obtaining ferro-manganese, there has been a tendency to use considerable spiegeleisen for open-hearth steel. As the United States is relatively an unimportant producer of the manganese ores from which ferro-manganese is obtained, the imports of ore coupled with the production of ferro-manganese and spiegeleisen form the barometer of the trade in this country. These statistics are given in the following table. The large percentage increase in spiegeleisen is significant.

The tonnage of ferro-manganese available for consumption, as represented by the sum of imports plus production, was 312,460 tons in 1916, compared with 201,805 tons in 1915 and 189,080 tons in 1914.

Although the domestic production of manganese ore is comparatively small, there is a very large output of manganiferous iron ore, chiefly from the Lake Superior district. This contains from 12 to 25 per cent. of manganese and is used either to make spiegeleisen or to mix with high-grade imported ore in the making of ferro-manganese. Some also is used in making high-manganese pig iron.

UNITED STATES PRODUCTION AND IMPORTS
(Long tons)

	Ore Imports.	Ferro-manganese.			Spiegeleisen.	
		Imports.	Av. Value per Ton. (*a*)	Production.	Imports.	Production.
1907	209,021	87,400	$61.27	55,918	48,995	283,430
1908	178,203	44,624	41.70	40,642	4,579	111,376
1909	212,765	88,934	38.19	82,209	16,921	142,831
1910	242,348	114,228	37.99	71,376	25,383	153,055
1911	176,852	80,263	37.56	74,482	20,970	110,236
1912	300,661	99,137	39.41	125,378	1,015	96,346
1913	345,090	128,070	44.37	119,496	77	110,338
1914	283,294	82,997	41.33	106,083	2,870	79,935
1915	320,782	55,263	60.31	146,542	200	93,282
1916	576,321	90,928	101.62	221,532	*Nil.*	194,002

(*a*) At foreign port, no freight or duty.

There is also a large production of manganiferous zinc residue from the treatment of New Jersey zinc ores. This product is smelted in the blast furnace to produce spiegeleisen.

All of the above domestic supplies of manganese made large increases in 1915 and still larger in 1916. Detailed figures are not yet available for 1916; those for 1915 and previous years are given below:

PRODUCTION OF MANGANESE ORES IN THE UNITED STATES (*a*)
(Tons of 2240 lb.)

Year.	Manganese Ores.				Manganiferous Ores.					Man. Zinc Ores.
	California.	Georgia.	Virginia.	Other States.	Arkansas.	Colorado.	Lake Superior.	Va. & N. C.	Other States.	New Jersey.
1902	846	3,500	3,041	90	*Nil.*	13,275	884,939	3,000	....	65,246
1903	16	500	1,801	508	*Nil.*	14,856	566,835	2,802	....	73,264
1904	60	*Nil.*	3,054	32	600	17,074	365,572	*Nil.*	....	68,189
1905	1	150	3,947	(*e*) 20	3,321	45,837	720,090	*Nil.*	....	90,289
1906	1	....	6,028	892	8,900	32,400	1,000,008	*Nil.*	....	93,461
1907	100	*Nil.*	(*d*) 4,604	900	4,133	(*d*) 99,711	(*d*) 314,316	*Nil.*	(*h*) 7,000	93,413
1908	321	*Nil.*	(*e*) 6,144	200	(*d*) 4,066	(*d*) 51,524	(*d*) 467,140	274	....	110,225
1909	3	*Nil.*	1,334	*Nil.*	(*d*) 3,325	(*d*) 65,024	(*d*) 775,035	305	....	141,264
1910	(*f*)	*Nil.*	2,059	199	(*d*) 5,030	(*d*) 55,770	(*d*) 558,634	301	....	137,173
1911	(*f*)	*Nil.*	(*g*) 2,457	*Nil.*	(*d*) 2,177	(*d*) 41,753	477,920	507	....	109,296
1912	(*f*)	*Nil.*	(*g*) 1,664	*Nil.*	(*d*) 1,332	(*d*) 48,618	816,984	1,567	....	104,670
1913	(*f*)	*Nil.*	(*g*) 4,048	*Nil.*	(*d*) 9,650	(*d*) 49,753	(*d*) 612,743	*Nil.*	....	(*d*) 102,239
1914	501	*Nil.*	1,724	410	1,970	39,881	402,754	1,222	....	100,198
1915	2,563	3,168	1,620	2,358	2,600	30,921	659,025	1,944	(*i*) 106,800	159,318

(*a*) Statistics of 1900–1906 are by the U. S. Geological Survey. (*b*) Includes 1300 tons of manganiferous iron ore from Vermont. (*c*) As reported by Virginia Geological Survey. (*d*) As reported by U. S. Geological Survey. (*e*) Estimated. (*f*) Figures not available. (*g*) Includes Tennessee and California. (*h*) New Mexico. (*i*) Arizona, Georgia, and Nevada.

The 1916 increase in domestic manganese ore was especially gratifying. Preliminary estimates of the U. S. Geological Survey, show that the production was about 27,000 tons, the greatest since 1888 and nearly three times that in 1915, which was 9709 tons. The estimate does not include the manganiferous iron ores that contain less than 40 per cent. of manganese. This output has come largely from seven States, and the order in production will probably prove to be as follows: California, Arkansas, Arizona, Georgia, Virginia, Utah, Colorado. This order is interesting, because this is the first year in which a Western State remote from the steel-producing centers has contributed the largest amount of manganese ore. The activity among manganese mines in California is due largely to the market for ores provided by the Noble Electric Steel Co. at Heroult.

Probably the most important use of manganese aside from the steel industry is in the making of dry batteries. This requires a very high-grade ore, containing about 80 per cent. of manganese dioxide and less than 1 per cent. of iron. Ores of this class are now produced in Arizona, California, Utah, Colorado, and Virginia, but the amount produced is still scarcely one-tenth the normal demand. Reports indicate that the 1916 production exceeded 2500 tons, five times that in 1915.[1]

Although a number of mines in Virginia, Georgia, and Arkansas were reopened during 1916, the greatest activity is reported among mines in California, Arizona, Utah, New Mexico, and other Western States. This is due in part to the operation of electric reduction plants in California and Washington, but more largely to the low percentage of iron in some of the Western ores. Few Eastern mines that operate residual deposits can produce at a profit in large quantities ore that contains less than 1 per cent. of iron, and therefore most of the Eastern mines ship their product to Eastern furnaces to be reduced to ferro-manganese. The inaccessibility of most Western deposits makes it unprofitable to ship ore to Eastern makers of ferro-manganese, even at the high prices they are now offering for manganese ore. At prevailing prices for the high-grade ores, they may be profitably shipped as far east as New York. There is a prospect at present that several Western mines may be able to ship such ores to Eastern markets even when prices recede to the level of years prior to 1914.

As shown in the table, the imports of manganese ore reached an immense total, increasing 80 per cent. over the large amount for 1915. In value they rose from $2,665,980 to $8,666,179. The value per long ton increased from $8.28 to $15.04.

The bulk of the increase in ore imports naturally was from Brazil, though there was also an increase from India, and the imports from the minor sources (chiefly Japan, Cuba, and Panama) were more than three times as great as in 1915. Russia was again unable to make shipments

[1] U. S. Geol. Surv.

to this country. The following table shows the receipts from the principal sources of supply:

	Brazil.	Russia.	India.
1905	114,670	24,650	101,030
1906	30,260	13,805	154,180
1907	52,922	1,000	95,300
1908	17,150	250	143,813
1909	35,600	14,486	145,140
1910	53,750	33,120	140,965
1911	41,600	19,103	106,580
1912	81,580	83,334	128,645
1913	70,200	124,337	147,587
1914	113,924	52,681	103,583
1915	268,786	......	36,450
1916	471,837	......	51,960

In contrast to our own manganese-ore imports are those of Great Britain for 1916, which were only 439,509 gross tons, or nearly 120,000 less than ours. It is the first time that the British imports have been less than our own. Our 1916 imports were not far from the British record in 1913.

The United States has had to supplement its production of ferro-manganese by importing large amounts from Europe, of which 90 per cent. has come from Great Britain. Since the war the latter has placed restrictions on ferro-manganese exports, with the result that our imports have been considerably reduced. However, under the stress of the 1916 demand they have again come up to the normal amount of previous years. And yet, whereas they formerly amounted to about 50 per cent. of the consumption, in 1916 they were only 29 per cent. thereof. England had an embargo on ferro-manganese from November, 1914, to March, 1915.

The resulting shortage in the United States has been met by an increase in domestic production. So far as information is available, it appears that the increase has been accomplished by the entrance of new makers into the field, rather than by increase in the output of those already in it. The number of makers of ferro-manganese in 1915 was eight, and there were several additional in 1916. The production of spiegeleisen has increased slightly, and several new makers entered the field in 1916.[1]

The production of manganese-steel rails in 1916 was 2069 long tons, against 3779 tons in 1915.

Prices.—The prices paid for manganese ore adapted to the manufacture of ferro-manganese rose from a maximum of $22.50 for 50 per cent. ore in 1915 to $32.50 in March, 1916. Except for minor fluctuations, which depended on temporary variations in demand, prices were nearly constant until the last month of the year, when sales at prices as high as $39 for 50 per cent. Indian ore were reported. There were rumors that a contract for the delivery of 200,000 tons of Brazilian ore

[1] D. F. Hewett, U. S. Geol. Surv., *Bull.* 666-C.

during 1917 was placed at $23 per ton f.o.b. Brazilian port, from which the freight rate to Baltimore is $12 a ton. Ore adapted to the manufacture of dry batteries continues to sell for about $85 a ton.

The high mark of the year recorded ore prices which were the highest in 30 years.

Prices of ferro-manganese furnished the most spectacular feature of the year in the manganese trade, rivaling the "stunts" of other war metals. De Courcy Browne describes this development in the Annual Review number of the *Iron Age:*

"Wide fluctuation occurred in the value of this metal in the past year, although final quotations were only about 25 per cent. higher than in January. The year opened with English ferro-manganese about $125 at seaboard, and at that time there was a decided shortage on account of the difficult shipping situation. The English alloy was rapidly advancing and $225 was obtained on urgent orders, although $150 had been the contract quotation for 1916 material, but no guarantee of delivery could be obtained from the manufacturers. Toward the end of March the shortage was more acute and buyers were very nervous about their sources of supply. A few carloads were sold as high as $400 to $500 per ton, although the nominal quotation was then about $175 seaboard.

"About a month later, several large cargoes came from abroad so that the situation was very much relieved. The price then gradually eased off until July. The market then settled at about $175 to $200, seaboard Since that time it has been rather stable, but at present is only fairly firm at $165 to $170.

"Several of the large steel companies are now manufacturing this alloy for themselves as well as for the outside trade, and several old blast-furnace stacks have been renovated and put on ferro-manganese. American producers are entirely dependent on ores from South America, Cuba and the Orient, our American ores having been very disappointing as far as tonnage is concerned. Some high-grade ores in limited quantities have come in from Japan."

The Engineering and Mining Journal says:[1] "The top prices of last winter were due to the depletion of domestic and European stocks of Caucasian, the sudden calls upon producers in other parts of the world finding them unprepared to make prompt deliveries in large volume. While the production of selected grades is now on a settled basis, some of the largest producers insist that further reductions will compel closing down. A hardening of prices on chemical, battery and other technical grades is to be expected with the elimination of the smaller war-time miners, which has already begun. Minimum 80 per cent. dioxide with

[1] Jan. 13, 1917.

maximum 1.6 per cent. iron and 0.05 per cent. copper is quoted at $60 per net ton in carloads, lump, with extra charges for milling or barreling. The linoleate and precipitated resinate are firm at 20 cts. per lb.; the fused resinate, at 10 cts.; the sulphate has dropped to 17 cts."

Average monthly prices for ferro-manganese at eastern seaboard, based upon actual sales for the past 5 years, have been as follows:

	1912.	1913.	1914.	1915.	1916.
January	$41.00	$65.00	$36.00	$68.00	$110.00
February	41.00	65.00	38.00	100.00	140.00
March	41.00	65.00	38.00	100.00	175.00
April	43.50	65.00	38.00	100.00	175.00
May	47.50	61.00	38.00	100.00	175.00
June	48.00	61.00	37.50	105.00	175.00
July	49.50	58.50	27.50	103.00	175.00
August	52.00	56.00	100.00	105.00	170.00
September	55.00	55.00	80.00	110.00	164.00
October	59.00	50.00	66.00	105.00	160.00
November	61.00	50.00	68.00	100.00	155.00
December	65.00	45.00	68.00	100.00	162.50

The price of spiegeleisen carrying 20 per cent. of manganese ranged from a maximum of $52 per ton in July to $40 in December. In 1914 it was about $25.

As long as the present demand for steel continues there is little prospect for greatly reduced prices of either manganese ore or ferro-manganese, and even when peace comes prices can scarcely decline to normal for at least 6 months or a year. Producers of manganese ore particularly should realize that never before for so long a period has there been a better opportunity for the profitable mining of manganese ore. They should realize also that this condition can not continue indefinitely.[1]

Mining.—One direct result of the shortage of manganese ore has been the stimulus to miners of manganiferous silver ores to select portions of the ore rich enough in manganese to be more valuable for this metal than for their small gold and silver content. Thus, one mine in the Tombstone district, Arizona, is treating a fairly large quantity of the raw ore in mills and producing a concentrate rich enough in manganese to be used in making dry batteries and ferro-manganese, while the tailing is shipped to smelters as a flux.

In Arkansas[2] interest has been aroused in deposits which have been known to exist for a long time, but which have never been developed. These are located in the Ouachita Mountains, extending from Polk County on the west to Pulaski County on the east. The economic deposits occur in shale and "novaculite," the latter being a sedimentary rock resembling dense fine-grained quartzite. It was formerly thought

[1] U. S. Geol. Surv.
[2] *Min. Sci. Press*, **113**, 947–948.

that veins of over 1 ft. in width were rare, but several prospects now show a width of 3 ft. and over of solid psilomelane. Ore gave returns of 50 to 60 per cent. Mn, up to 8 per cent. SiO_2, and about 0.2 per cent. P. Mining conditions are good. Operations have been started in a small way.

Deposits very similar to the above occur in California, according to D. C. Billick.[1] They have not been developed. However, some high-grade ore deposits in the State have been worked for some time, and in 1916 all records for the State's production were broken. The Thomas mine, near Ukiah, Mendocino County, continued to ship large amounts of ore to Heroult, Shasta County, where the Noble Electric Steel Co. produces ferro-manganese in electric furnaces.

It is reported that experiments are being made to concentrate some of the lower-grade ores of the Cuyuna range, Minnesota, by removing part of the iron minerals. The development of the higher grades is being pushed to the full extent, and the workings are still by far the most important in the United States.

South Carolina is not at present a producer of manganese, but according to R. W. Petre[2] there is a good deposit near the town of McCormick, occurring in connection with the ore of the old Dorn gold mines. The shipping ore contains an average of 43 per cent. Mn, 0.16 P, 5.00 SiO_2 and 2.10 per cent. Fe, and is composed of an irregular mixture of pyrolusite and psilomelane which, being hard, can be kept apart from the wad. The last shipment of ore was made in 1914 to the Tennessee Coal and Iron Co.—about 500 tons, while the past history of the mine shows shipments to have been regularly made, prior to the war, to England from Augusta, Ga., by rafts and boats down the Savannah River to seaboard.

One of the most interesting of the recent discoveries of manganese is in Bradley County, Tennessee, about 8 miles south of Cleveland and about 1 mile east of Weatherly, a siding on the Southern R. R. The ore is of excellent quality, very low in phosphorus and silica and high in manganese-content. Unfortunately, however, it proved to be too high in iron for use in the manufacture of dry batteries. Two average analyses of the ore are as follows:

Phosphorus	0.142	0.100
Silica	0.70	0.50
Iron	3.33	2.24
Manganese	54.20	56.10

Up to the present only about 200 tons of the ore has been shipped, which has all been taken from within a few feet of the surface. The pits and open cuts have been located without regard to system or econ-

[1] *Min. Sci. Press*, **114**, 327.
[2] *Eng. Min. Jour.*, **101**, 1019.

omy. Men were set to work anywhere that a small amount of float could be found, and at first one man would some days dig out from 1 to 2 tons of ore. Some of the blocks of ore weighed from 400 to 600 lb. and had to be broken up before they could be lifted from the pits. Some of the pits showed but little ore and some were entirely barren. In one field about 10 tons of ore was simply plowed up from within a foot of the surface. As the mine was being developed by several local men who were not experienced in mining, this splendid surface showing of course caused considerable excitement. They have later, however, gotten down to a working basis and are now stripping the top of a low hill along the zone in which the manganese is disseminated.

Manganese deposits are known to occur in several places in the eastern part of Tennessee. A large number of these are described by A. H. Purdue, State Geologist.[1]

Ore carrying 45 to 50 per cent. manganese was mined near Marysvale in Piute County, Utah, and shipped to Chicago and Pennsylvania points.[2]

Virginia has contributed in the past more heavily than any other State to the domestic production. Five of the six deposits in the State are on the east side of the valley that lies west of the Blue Ridge and is commonly known as the Great Valley of Virginia. They coincide roughly in position with the outcroppings of a group of Cambrian shales and quartzites. The other deposit lies well east of the Blue Ridge, in the piedmont region. Psilomelane is the commonest manganese mineral of all the ores, but manganite and wad are also present. The ores are all of near-surface origin and were formed mainly through the replacement of clays and schist by manganese carried in solution in the ground water. Some of the clays replaced were the residual products of rock weathering, others were deposited in ancient stream channels, and still others were formed through the crushing of wall rocks along zones of fracturing. The greatest depth to which the ores have been traced is 260 ft. It is considered improbable that manganese ores in any of the Virginia or Maryland deposits will extend to depths of more than 500 ft.[3]

Foreign Countries

It is impossible to obtain statistics from many of the foreign countries and reports in general are much delayed. In many countries activity has been proportional to that in the United States, while in others the effect of the war has been the reverse, principally due to the difficulty of shipping.

[1] *Res. of Tenn.*, April, 1916, pp. 111–123.
[2] *Eng. Min. Jour.*, **103,** 103.
[3] *Min. Eng. World*, Sept. 2, 1916.

WORLD'S PRODUCTION OF MANGANESE ORE (*a*)
(In metric tons)

Year.	Austria-Hungary.	Belgium.	Bosnia. (*b*)	Brazil. (*d*)	Canada.	Chile. (*d*)	Colombia.	Cuba.	France.	Germany.	Greece.	India.
1903	11,489	6,100	4,537	161,926	135	17,110	(*c*)	21,070	1,583	47,994	9,340	174,563
1904	15,460	485	1,114	208,260	123	2,324	(*c*)	33,152	11,254	52,886	8,549	152,601
1905	23,732	*Nil.*	4,129	224,377	22	1,323	(*c*)	(*d*) 8,096	6,751	51,463	8,171	250,788
1906	20,577	120	7,651	121,331	84	35	(*c*)	(*d*) 13,997	11,189	52,485	(*d*) 9,200	579,231
1907	24,954	2,100	7,000	236,778	1	(*c*)	(*c*)	30,486	18,200	74,683	10,000	916,770
1908	27,257	7,130	6,000	166,122	*Nil.*	1	(*c*)	1,492	15,865	67,692	10,750	685,135
1909	29,966	6,270	5,000	240,774	*Nil.*	(*c*)	(*c*)	2,976	9,378	77,177	5,374	654,974
1910	28,964	*Nil.*	4,000	253,953	*Nil.*	(*c*)	(*c*)	(*c*)	7,925	80,559	41	813,761
1911	15,954	*Nil.*	3,600	213,000	5	(*c*)	(*c*)	(*c*)	6,036	87,297	733	681,015
1912	12,471	*Nil.*	4,650	154,870	68	(*c*)	(*c*)	(*c*)	5,576	92,474	7,719	643,209
1913	16,540	*Nil.*	4,700	122,300	*Nil.*	(*c*)	(*c*)	(*c*)	7,732	330,797	(*f*) 556	828,088
1914	(*h*)11,413	(*c*)	4,120	183,630	25	(*c*)	(*c*)	(*c*)	(*c*)	(*c*)	(*f*) 558	693,824
1915	(*c*)	(*c*)	(*c*)	288,671	182	(*c*)	(*c*)	(*c*)	(*c*)	(*c*)	408	457,668
1916	(*c*)	(*c*)	(*c*)	503,130	888	(*c*)	(*c*)	(*c*)	(*c*)	(*c*)	(*c*)	(*c*)

Year.	Italy.	Japan.	New Zealand.	Portugal.	Queensland.	Russia.	Spain.	Sweden.	United Kingdom.	United States. (*e*)
1903..	1,930	5,616	71	30	1,341	414,334	26,194	2,244	831	671,151
1904..	2,836	4,324	199	(*c*)	843	430,090	18,732	2,297	8,880	461,854
1905..	5,384	14,017	55	(*c*)	1,541	508,635	26,020	1,992	14,582	877,482
1906..	3,060	54,339	16	22	1,131	1,015,686	62,822	2,680	23,126	1,141,681
1907..	3,654	20,589	26	1,374	1,134	995,282	41,504	4,334	16,356	517,177
1908..	2,750	11,130	*Nil.*	....	1,403	362,303	16,945	4,616	6,409	650,559
1909..	4,700	8,708	6	....	613	574,938	7,827	5,212	2,812	1,002,939
1910..	4,200	11,120	5	....	805	(*d*)668,050	8,607	5,752	5,554	771,818
1911..	3,515	9,787	1	6	1,000	(*d*)584,000	5,607	5,377	5,067	644,678
1912 .	2,641	12,060	*Nil.*	6	313	(*d*)766,000	19,936	5,101	4,237	991,082
1913..	1,622	2,313	*Nil.*	*Nil.*	27	1,171,000	21,594	4,001	5,480	791,407
1914..	1,649	17,076	*Nil.*	*Nil.*	6	737,300	(*c*)	3,643	3,496	557,804
1915..	12,577	25,870	*Nil.*	(*c*)	. 203	(*g*) 50,000	14,328	7,607	4,716	985,939
1916..	(*c*)	(*c*)	(*c*)	(*c*)	653	(*g*)150,000	(*d*)6,815	(*c*)	(*c*)	(*c*)

(*a*) Official statistics. (*b*) Includes Herzegovina. (*c*) Statistics not available. (*d*) Exports. (*e*) Includes manganiferous iron ore. (*f*) Sales. (*g*) Estimated. (*h*) Hungary.

Brazil.—This country has now become the chief reliance for the United States supply. As a result, the production registered an increase of 58 per cent. in 1915 and a further increase of 74 per cent. in 1916. The value of the 1916 output was $7,180,000, or more than $14 per ton, at Rio de Janeiro. This was nearly the value of the 1915 production.

F. L. Garrison investigated the manganese deposits of Brazil. He says:[1] "New and larger deposits have been opened up in the Lafayette or Queluz district. To-day the Morro da Mina is not only the most important one in that region but is probably the largest manganese mine in the world, and curiously enough this property some 10 or 15 years ago in its then partly developed condition, was considered almost worthless, a circumstance attributable to the lack of knowledge concerning the geology of the region in general and of the genesis of the deposits in particular. The Morro da Mina mine is owned and operated by Brazilians; the Cocuruto, the next largest, has an English manager and is

[1]*Min. Sci. Press*, Mar. 10, 1917.

controlled by Belgian interests. Practically all the manganese ore produced in Brazil is sent to the United States; England and France obtain their supplies from India."

Mr. Garrison points out the remarkable purity of the Brazilian ores, which usually contain less than 6 per cent. of iron, with phosphorus and silica falling well within the Carnegie Steel Co.'s specifications, which govern in the American market. The manganese shipped from the State of Bahia, Brazil, seldom exceeds 4 per cent. in silica, 5 per cent. in iron, and 0.017 per cent. in phosphorus.

Colombia.—It is reported that an American syndicate has opened a manganese ore mine at Madinga, on the Gulf of San Blas, in the Province of Colon, Colombia, and that a trial shipment of some 900 tons of the ore was made recently to New York. Shipments of 1500 tons a month are anticipated if vessels are available for the purpose, and a wharf at deep water has been built near the mine.[1]

Costa Rica.—One manganese mine is in operation in Costa Rica. It began shipping in May, 1916, and is now sending out about 300 tons a month, all in bags. It is making preparations to install an equipment of docks, furnaces, etc., with a capacity of 3000 to 5000 tons a month. This equipment probably will be completed by July 1, 1917. Facilities for loading ocean steamers from its own docks are to be provided. Its port will be about 2 miles south of Braxilito (Brazilito), which is a little north of Morro Hermoso, on the Pacific side, considerably north of the Pacific port of Puntarenas. The plant is at Playarreal, Guanacasto, Costa Rica. The ore is given as averaging 55 per cent. metallic manganese, or for chemical purposes, 80 to 83 per cent. manganese dioxide. Other claims have been selected, but no other company has begun operations.[2]

Cuba.—The manganese industry of Cuba, which dates back 20 years, has been continued with interruptions up to the present time.

The three generally recognized groups or deposits of ore within this district are known as Cristo, Cauto, and Ponupo, the latter being the largest and having produced up to the present about 2,000,000 tons. It is still producing about 3000 tons per month of a fair grade of furnace ore that averages about 43 per cent. metallic contents. The Cristo group is producing a small amount of ore that runs about 46 per cent., while the Cauto group is producing about 2000 tons per month; it has also shipped several small cargoes of dioxide. The three groups are operated by two companies—the Ponupo and Cristo groups by Aguilera & Co. and the Cauto group by the Cauto Mining Co.

[1] *Min. Eng. World*, July 15, 1916.
[2] *Comm. Rept.*, Jan. 24, 1917.

The manganese operations in this section during 1915 were held back chiefly through lack of labor and inadequate transportation facilities both by land and by sea. Practically all of the ore produced was shipped to Baltimore with the exception of a small consignment for the Italian Government. None of the ore is treated in any of the mines here, except by log washing to remove the dirt. The furnace ore is shipped in bulk and the dioxide in sacks.

During the year the mining companies spent considerable money in improving their properties. There still remain in this Province large undenounced and undeveloped deposits of manganese, no particular attention having been given to them on account of inadequate transportation facilities; but the outlook, if the demand and good prices continue, is quite favorable.[1]

Germany and Austria-Hungary.—German imports of manganese ore from Russia and India averaged in the last 7 years before the war about 450,000 tons. In 1913 total imports were 680,371 tons.

The want of manganese is being severely felt, and orders have been issued for all known deposits to be developed. Previous to the war the output of low-grade ores was 92,474 tons from Prussia, most of it from the Bonn district. The only deposit producing what is commercially considered manganese was that at Giessen, and the output was only a few hundred tons a year. In Austria-Hungary the production in 1912 was 12,471 tons of low-grade stuff, while from Bosnia and Herzegovina there was an output of 4650 tons of somewhat higher-grade ore. A small production of manganese has also been obtained from mines in Asia Minor and Macedonia. There was also a considerable output of manganiferous iron ore. When, however, it is remembered that the net import into Germany alone in the year previous to the war was 680,000 tons, the inadequacy of these native deposits will be realized.[2]

The region of Siegen and Nassau in Germany has been extensively developed for a manganiferous iron ore containing 15 to 20 per cent. manganese, which is used to make a low-grade ferro of 30 to 40 per cent. The slags are resmelted to enrich them in manganese and then used as fluxes. But they have been forced to use large amounts of ferro-silicon and silicon-spiegel in place of ferro-manganese.[3]

The Siegerland mines yield about 1,750,000 tons yearly of 12 per cent. manganiferous ore.

E. F. Cone has written an important article on Germany's supplies of ferro-manganese.[4] He concludes that, regarded from the most favorable

[1] *Comm. Rept.*
[2] *Min. Jour.*, Apr. 14, 1917.
[3] *Echo des Mines*, Nov. 12, 1916.
[4] *Iron Age*, **98**, 1453–5.

viewpoint, their need was very pressing within at least a year after the war was started. Commenting on this article, Frank Jovic says:[1]

"One thing is indisputable, Germany is very short of manganese, and all substitutes have failed to give satisfactory results, in spite of the assertions in the daily press. This is emphasized by the commandeered silence on the question of steel quality and the high price the German iron works are willing to pay for high-grade manganese ore. The substitutes that were tried out were more costly and yielded such poor results that ferro-manganese is still the most used recarburizer of steel.

"The greatest hopes were based on calcium carbide, but it failed to give results in persistent tests, made on a large scale during many months. The main reason is the action of the calcium on iron. Calcium is all right for deoxidation, but inert to iron.

"Greater success seems to be secured by the use of thermit-aluminum products, advertised previous to the war, although their use necessitates caution and is far from general."

During the past year, piles of slag from old ferro-manganese furnaces in Westphalia running from 5 to 14 per cent. manganese, have been drawn upon, and U. S. Consul Albert, of Brunswick, Germany, reports that the village of Adenslidt has been demolished to secure manganese ore running about 22 per cent. manganese. Lately complaint is reported from Dutch sources in regard to the quality of German steel. It is said that the steel is daily proving worse and is becoming hard and brittle. The deterioration is attributed to lack of skilled workmen and to the lack of manganese.[2]

A paper by H. K. Scott, presented at a meeting of the Iron and Steel Institute (London), describes the manganese deposits in Bukowina, which, though not of high grade, are richer than any deposits continuously worked in Germany or the Austrian Empire. These deposits are in the neighborhood of Jacobeni, in the southwest of Bukowina, near the borders of Roumania and Hungary. The average ore assays 33 per cent. manganese, and after the richer parts are removed by hand-picking, the remainder is crushed and jigged. The ore contains phosphorus, and the price of the concentrate is governed thereby. Previous to the war, the Witkowitz company, in Austrian Silesia, was a large buyer of the concentrate for ferro-manganese manufacture, and glass and chemical makers bought the picked ore. Just before the war, at the time of Mr. Scott's visit, schemes were in hand for the expansion of mining operations.[3]

[1] *Iron Age*, **99**, 496.
[2] *Bull. Amer. Inst. Min. Eng.*, Feb., 1917.
[3] *Queens. Govt. Min. Jour.*, Dec. 15, 1916. See also *Eng. Min. Jour.*, **102**, 935–7.

India.—The production of India showed a further decline of 34 per cent. in 1915, after having decreased 16 per cent. in 1914.

Manganese-ore exports from India for the fiscal year 1915–1916 were 472,563 gross tons, against 440,590 tons in the previous fiscal year. The United Kingdom took 380,967 tons, or over 80 per cent., of the last fiscal year's total, against 227,281 tons, or 51 per cent. of the previous year's total. The exports to the former principal customers, the United States and France, were reduced 26,103 tons and 26,326 tons to 47,400 tons and 20,000 tons respectively. These data are from the *Review of the Trade of India in* 1915–1916 by the Director of Statistics.

There was some discussion in England in regard to German influence in the Indian manganese trade. It is understood that thorough reorganizations have eliminated danger from this source.

Mexico.[1]—In a recent issue of the *Boletin Minero* is contained an interesting article on the group of manganese mines at Concepcion Point, Lower California. These mines, which are reported to be the richest known deposits of this element in the world, are situated in the arid hills of a small peninsula, 25 miles long and from 5 to 8 miles wide, between the coasts of the Gulf of Lower California and Concepcion Bay. The Pilares de Gavilan mines consist of 15 claims, the outcropping veins being from 1 to 5 ft. thick, and are estimated to contain 1,733,333 tons of pure manganese. The Trinidad mines have ore veins which vary from a few inches to 16 ft. in thickness, and the Guadalupe mine has veins of this ore from 5 to 6 ft. thick.

Nicaragua.—Rapid progress is being made in the development of the manganese mine at Playa Real, Nicaragua, according to the U. S. Department of Commerce. The mine appears to have a large quantity of ore lying more like a blanket than as a vein formation. The principal mining method is that of stripping the surface. Large wharves that will permit the loading of the ore directly by overhead trolleys are contemplated.

Russia.—No other country in the world has such a wealth of manganese as Russia. There are two great manganese districts, one in the Province of Kutaïs and County of Sharapan, which extends over the whole central part of the basin of the River Kvirila, and in which the richest mines are situated, and the other in the Province of Ekaterinoslav. The beds of manganese ore are interstratified with sand and clay of Eocene age. The richest deposits cover an area of more than 50 square miles. The quantity exported from Batoum and Poti in normal times is annually about 1,000,000 metric tons.[2]

War conditions have now practically forced the cessation of the in-

[1] *Min. Jour.*, June 24, 1916.
[2] *Queens. Govt. Min. Jour.*, Mar., 1917.

dustry except for the small local requirements, which are probably not over 40,000 tons, and a limited amount of land shipments. Data given by the Council of Congresses of Miners of Manganese Ore[1] state that 9769 tons of Chiatouri ore was shipped in 1916 from the ports of Poti and Batum, against 9750 tons in 1915 and 788,214 tons in 1914. By the Chiatursk side line 131,934 tons was forwarded in 1916, of which 60,742 tons was sent further by land. The price of the ore in the first quarter of 1916 was $2.50 to $3 per long ton, but has advanced to $6.50 to $7.

The Chiatouri deposits are estimated to contain 110,000,000 tons of manganese ore. These and other Russian deposits are described at length by E. C. Harder, with further discussion by Herbert K. Scott.[2]

A company with a capitalization of 10,000,000 roubles has been formed for the exploitation of manganese mines and works in the Province of Coutais (Caucasus) and other provinces of Russia.[3]

Spain.—Shipments of ore in 1916 were 6815 tons, compared with 9136 tons in 1915.

Technology

An important consequence of the prevailing high prices of manganese alloys is the attempt on the part of steel makers to use substitutes. The increased use of spiegeleisen in place of ferro-manganese has been previously noted. Ferro-titanium is being used as a substitute in this country, and appears to give much promise. Ferro-silicon is another important substitute. German experience with substitutes is noted on another page. It is stated that the Germans may also be using calcium silicide. In regard to the use of calcium carbide, U. S. patents No. 868,610 and No. 1,081,532 should be noted.

The presence of manganese in slags and the possibility of utilizing it has been given increased attention. Over 2,000,000 tons of basic slag, containing 85,000 tons of manganese, is made yearly in the United States, and 80 to 90 per cent. of this is wasted.[4]

There is an increased use of electric furnaces in the production of ferro-manganese, and experimental work is being done along this line. It is an important fact in connection with the scarcity of ferro-manganese that less is required for electric furnace steel, and there is also a smaller loss of the amount used when the addition is made in the electric furnace. With the great increase in electric-furnace steel, this should become an important saving.

[1] *Iron Age*, Jan. 27, 1917.
[2] *Bull. Amer. Inst. Min. Eng.*, May, 1916 and Dec., 1916. See also *Min. Mag.*, Feb., 1917.
[3] *Echo des Mines et Métallurgie*, July 20, 1916.
[4] *Iron Age*, Apr. 12, 1917.

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MICA

By J. Volney Lewis

During the year 1916 North Carolina and New Hampshire are reported to have kept up about their normal output, with prices advancing somewhat throughout the year. The average price of sheet mica in the United States advanced from 21 cts. a pound in 1913 to 50 cts. in 1914, and 68 cts. in 1915,[1] and the industry in the principal producing regions has been in a prosperous condition. North Carolina continues to furnish more than half the domestic output, but the chief supply of the mica industries is still obtained through imports, which come mostly from India.

The American product is cut into sheets for stoves, punched into washers of various sizes, and the scrap is ground. The bulk of the "splittings," however, the chief material of the mica trade, comes from India. Amber mica, specially adapted for use in commutators, continues to come only from Canada. In August the Canadian Government placed an embargo on the exportation of mica and micanite to destinations outside of the British Empire. It was arranged, however, to grant special licenses for exportation of shipments consigned to the order of the British consul general, New York, for purchasers approved by him and upon the furnishing of the required guarantees.

Domestic Production.—The following table shows the production of mica in the United States during the past 12 years, as reported by the United States Geological Survey, in comparison with the total value of imports, from statistics of the Department of Commerce.

PRODUCTION OF MICA IN THE UNITED STATES[2]

	Sheet Mica.		Scrap Mica.		Total Value.	Value of Imports.
	Pounds.	Value.	Short Tons.	Value.		
1906	1,423,100	$252,248	1,489	$22,742	274,990	$1,042,608
1907	1,060,182	349,311	3,025	42,800	392,111	925,259
1908	972,964	234,021	2,417	33,904	267,925	266,058
1909	1,809,582	234,482	4,090	46,047	280,529	618,813
1910	2,476,190	283,832	4,065	53,265	337,097	725,823
1911	1,887,201	310,257	3,512	45,550	355,804	505,552
1912	845,483	282,823	3,226	49,073	331,896	755,584
1913	1,700,677	353,517	5,322	82,543	436,060	947,780
1914	556,933	278,540	3,730	51,416	329,956	665,743
1915	553,821	378,259	3,959	50,510	428,769	696,112
1916	....	....	....	....	....	1,130,563

[1] *Min. Res. of U. S.*
[2] Imports include the value of ground mica, first reported in 1910.

Imports.—As shown in the preceding table, the total value of mica imports during 1916 amounted to $1,130,563, an increase of 62.76 per cent. over that of the preceding year. This sets the high-water mark of imports. The only other year when the million-dollar mark was reached was in 1906, when the total value was $1,042,608.

The accompanying table of imports shows that there have been increases in every class of mica, with the greatest advance in the untrimmed, or unmanufactured grade, which nearly doubled in value in comparison with that of the preceding year. The average price in this grade, which dropped from 36.68 cts. a pound in 1913 to 24.22 cts. in 1914, has advanced steadily since, so that the pre-war price has now been surpassed. In 1915 it was 32.57 cts., and in 1916 it rose to 40.91 cts. a pound.

The classification of mica imports for the fiscal year ending June 30, 1916, shows that 31.3 per cent. of the uncut mica averaged 9.8 cts. a pound, while 68.7 per cent. of it had the average value of 68.6 cts. a pound.

IMPORTS OF MICA INTO THE UNITED STATES[1]

	Unmanufactured.		Cut or Trimmed.		Ground.		Total.
	Pounds.	Value.	Pounds.	Value.	Pounds.	Value.	Value.
1907	2,226,460	$848,098	112,230	$77,161	....	....	$925,259
1908	497,332	224,456	51,041	41,602	....	....	266,058
1909	1,678,482	533,218	168,169	85,595	....	....	618,813
1910	1,424,618	460,694	536,905	263,831	....	$1,298	725,823
1911	1,087,644	346,477	241,124	155,686	....	3,389	505,552
1912	1,900,500	649,236	88,632	99,737	....	6,611	755,584
1913	2,047,571	751,091	46,336[2]	191,924	290,757	4,765	947,780
1914	845,904	204,850	........[3]	456,805	404,840	4,088	665,743
1915	779,922	244,292	....	447,962	344,040	3,858	696,112
1916	1,151,494	471,204	....	655,067	436,037	4,302	1,130,563

[1] Statistics from Bureau of Foreign and Domestic Commerce.
[2] From Jan. 1 to Oct. 3.
[3] Quantities not reported.

Exports.—Before the war mica exports went chiefly to Germany and Belgium; now Canada and England are the chief customers, as shown by the following table. It will be noted that the value of unmanufactured mica exported increased 60 per cent. in spite of a great decline in quantity, since the average price increased from 2.3 cts. a pound in 1915 to 9.5 cts. in 1916. Manufactures of mica increased from $24,336 to $53,524, or 120 per cent., and the total value of exports also increased more than 100 per cent.

EXPORTS OF MICA FROM THE UNITED STATES[1]

	Unmanufactured.		Manufactured Value.	Total Value.
	Pounds.	Value.		
1912	356,601	$14,936	$25,876	$40,812
1913	298,711	14,175	48,009	62,184
1914	433,329	25,962	39,140	65,102
1915	214,371	5,019	24,336	29,355
1916	84,744	8,082	53,524	61,606

[1] Bureau of Foreign and Domestic Commerce.

DESTINATION OF CHIEF MICA EXPORTS[1]

	Year Ending June 30, 1914.				Year Ending June 30, 1916.			
	Unmanufactured.		Manufactured Value.	Total Value.	Unmanufactured.		Manufactured Value.	Total Value.
	Pounds.	Value.			Pounds.	Value.		
Germany	172,364	$11,215	$1,554	$12,769	....	....	....	....
Belgium	148,335	9,372	3,252	12,624	....	....	....	....
France	....	....	7,330	7,330	1,216	$1,316	$396	$1,712
England	61,216	2,721	4,943	7,664	17,989	1,030	17,306	18,336
Canada	38,080	2,136	18,236	20,372	61,993	2,817	15,103	17,920
Japan	....	....	....	117	706	400	10,307	10,707
Sweden	....	....	....	....	1,558	1,529	595	2,124

[1] Bureau of Foreign and Domestic Commerce.

Mica Production in India[1]

Following a decrease of 12.5 per cent. in mica production in 1914, there was a further decline in the output of India for 1915, which amounted to 24,063 cwt., in comparison with 38,189 cwt. for 1914, a decrease of 36.99 per cent. This was the smallest output since 1910. More than half of the total came from the Hazaribagh district in Bengal.

The war has had a great effect on the mica trade, partly owing to the restrictions placed by the Government on its export to various countries. These restrictions and the loss of the German market had an adverse effect on the sale of all grades of splittings. The chief demand was for good clear and part-stained block mica for use, among other things, for the magnetos of airplanes.

The trade in Madras was especially depressed, having declined nearly 50 per cent. during 1915.[2] Nellore is the chief center for mica in Madras, although some is produced in the Salem district. It is sorted according to color and size and is packed loose in wooden boxes lined with paper.

[1] *Rept.* Chief Inspector of Mines in India for 1915.
[2] Consul L. Memminger, Madras, *Comm. Rept.*, Apr. 4, 1917.

Mica Produced in Canada

The total value of mica output in Canada increased from $91,905 in 1915 to $122,541 in 1916, an advance of 33.23 per cent. The value of exports increased from $236,124 to $379,720, or 60.82 per cent.; and the average price per pound of mica exported advanced from 26.8 cts. in 1915 to 29 cts. in 1916. It is to be noted that the total value of the mica output at the mines for the past 7 years was only $973,923, while the value of exports for the same period was $1,943,064, an increased valuation of 99.5 per cent., largely attributable to beneficiation.

As in former years, the bulk of mica exports from Canada was sent to the United States. The figures for the latter are for fiscal years ending June 30, and therefore not strictly comparable with those for total exports from Canada, still they show that more than 91 per cent. of the total value came to the United States in the 7-year period. For 1915–1916 the value was $295,174 and there were return shipments to Canada to the value of $18,336, or a little more than 6 per cent., chiefly in the form of manufactures.

STATISTICS OF MICA IN CANADA

	Production,[1] Value.	Exports.[1]		Exports to U. S.[2]			
		Pounds.	Value.	Pounds.	Value.	Cut Mica.[3]	Total Value.
1911	$128,677	693,940	$242,548	632,091	$239,964	....	$239,964
1912	143,796	895,338	334,054	724,849	213,750	....	213,750
1913	194,304	817,152	240,775	1,277,252	218,365	....	218,365
1914	109,061	669,163	178,940	679,215	124,785	$42,471	167,256
1915	91,905	879,631	236,124	507,922	69,481	136,700	206,181
1916	122,541	1,308,793	379,720	709,614	79,834	215,340	295,174
Totals	790,284	....	1,612,161	....	....	....	1,340,690

[1] Dept. of Mines, Canada
[2] Years ending June 30. Bureau of Foreign and Domestic Commerce.
[3] Value reported separately, without quantity, after Oct. 3, 1913.

Mica in Brazil[1]

Almost the whole of the Brazilian mica output comes from the State of Minas Geraes, where it is mined along the sides of the Cayama and Popogais Mountains in the vicinity of Santa Lucia de Carangola, on the border of Espirito Santo. The country ranges from 2500 to 4000 ft. above sea-level and is thickly wooded. For this reason and also on account of the deep decomposition of the rocks, the outcrops are not easily found. The pegmatites, in which the mica occurs, are located here and there, however, by projecting bosses of quartz. The country rock is schist, in which the mica-bearing veins vary from 20 in. to 10 ft. wide, consisting

[1] A. F. Calvert, *Min. Res. of Minas Geraes (Brazil)*, London (1915).

chiefly of kaolin, from the decomposition of the feldspar of the pegmatite, and in which are disseminated irregularly the "books" of mica. Some of these are as large as 6 in. by 10 in. by 20 in. in size, but the average is much smaller. Only a small proportion of the mica mined is of sufficiently good quality for export. This is especially true of that which is obtained near the surface, where weathering agents have affected its quality.

Favorable conditions for the production of mica are (1) the low cost of mining on account of the decomposed condition of the rocks; (2) the good quality of the mica; and (3) in the Santa Lucia district, its contiguity to the Leopoldnia railway.

Mica in the Transvaal[1]

The Oliphants River mica belt is 143 miles from Komati Poort and 200 miles from Delagoa Bay. Mica Siding, about 3 miles north of the river is in the center of the mica district. The country is thickly wooded and in many places the bush is almost impenetrable. There is one main road from Mica to Leydsdorp, but otherwise the only roads are Kaffir footpaths. Makoutsie River is the only tributary of Oliphants that flows continuously and furnishes the only water supply for the miners of the district.

The mica is muscovite in pegmatite, which intrudes the older gneisses and mica schist in characteristic irregular fashion. Little systematic prospecting has been done, but the east-west trend of the leads is well determined, and the quality of the mica varies in the different veins. A green mica occurs in thick veins and huge pockets, but much of it is lost on account of the manner in which it breaks up on dressing. A spotted and stained mica, formerly thought to be unsuited for electrical work, has been found well adapted to this purpose and has brought good prices in the London market. A third variety is a clear brown of excellent quality, often found in large sizes and free from flaws, and when split is beautifully clean and elastic. The green variety is found in the more southerly veins, the clear brown at the north, and the stained mica, sometimes mixed with a little of the green, in intermediate veins.

The bulk of the work heretofore done has been confined to the green veins, which are larger, but the results have been so disappointing in the yield of merchantable material that most of the openings have been abandoned. One company working in the brown is producing a good percentage of sizes over 1½ by 4 in. All work is done by the open-quarry method, which the hilly character of the country will permit for

[1] W. T. Hallimond, *Min. Mag.*, May, 1916, p. 269.

many years to come. Besides being cheaper, this method also permits the extraction of the mica "books" in much better condition than would be possible in narrow underground stopes.

Good deposits of commercial mica exist for many miles to the east of the railroad, toward the border of Portuguese East Africa, and the expenditure of more money in careful prospecting appears to be worth while. A drawback to the development of the district is the Government's liberality in allowing claims to be held for a license fee of only 1d. per claim for the first year and 6d. per claim for the second, so that many claims are held on speculation without working.

A sample of about 600 lb. is reported to have been taken from a prospecting trench 62 ft. long, in which the mica is said to occur over a width of 6 ft. for the whole distance, without reaching the end of the deposit.[1] The average size of the sheets is given as 4 by 5 in.

Mineralogy and Geology of Mica

Varieties.—Two of the many known varieties of mica still continue to furnish the commercial supply of these minerals, which have come in recent years to have such a wide application as insulating materials in the electrical industries.

White mica (potash mica) is the most extensively used and is the only kind produced in most mica mining countries. As a rule it is nearly colorless in thin sheets, hence the name "white mica," but in places $\frac{1}{16}$ in. or more in thickness it shows a variety of shades of gray, green, yellowish-brown, and dark red. Chemically this mineral is a silicate of potassium, aluminium, and hydrogen, and its mineralogical name is muscovite.

Amber mica, sometimes also called bronze mica, and known by the mineral name phlogopite, is the other important variety. It is pale yellow to yellowish-brown and brownish-red in thin sheets, and ranges from these shades to nearly black in many thicker masses and crystals. It is a silicate of potassium, magnesium, aluminium, and hydrogen. This variety is the commercial mica of Canada, although deposits of muscovite also occur there and small amounts of it are sometimes mined.

Occurrence.—India, the United States, and Canada, in the order named, are the chief sources of the world's supply of mica. It is also produced in smaller amounts and much more irregularly in Brazil, German East Africa, Transvaal, Ceylon, Norway, China, Japan, Argentina, and South Australia. "Mica deposits of probable value have been found in about half the States of the United States. The principal

[1] *So. Afr. Min. Jour.*, Sept. 2, 1916.

producing States have been North Carolina, New Hampshire, South Dakota, Idaho, New Mexico, Colorado, Virginia, South Carolina, Alabama, and Georgia."[1]

Muscovite, or white mica, occurs in all the countries and States named as a constituent of a very coarse-grained rock related to the granites and known as pegmatite. The rock occurs in dikes and irregular intrusive masses and stringers in a variety of metamorphic crystalline rocks, such as gneisses, schists, and crystalline limestones. The great irregularity in form and extent of the pegmatites, and particularly the great variation in the proportions of mica contained, are among the serious difficulties attending the prospecting and exploitation of this mineral.

Phlogopite, or amber mica, is produced commercially only in Canada, where it occurs in or closely associated with a series of dike-like bodies of a pyroxene rock which intersects gneisses and crystalline limestone. Similar occurrences of phlogopite are known in several places in northern New Jersey and produced some mica for stove and other glazing purposes many years ago. They have not been worked, however, since the development of the electrical uses of the mineral.[2]

Mining and Treatment of Mica[3]

The irregular occurrence of mica makes it impossible to lay down any fixed rules for mining. If the pegmatite in which it occurs is in sheet-like bodies and the mica content is not too variable, ordinary straight mining methods may be followed; that is, by means of shafts, adits or tunnels, drifts, and stopes. If, as usual, both the form of the pegmatite masses and the mica content are variable and irregular, more irregular methods must be followed. Where the pegmatite forms large masses with commercial quantities of mica, open-cut methods, or quarrying, may be adopted, as in most of the smaller American mines, both north and south.

Ordinary mine-run mica consists of rough crystals and blocks, ranging from small grains and scales to 1 or 2 ft. across and, more rarely, several feet in diameter. These are treated by cobbing, splitting, rough-trimming, sorting, cutting into patterns, building up into large composite sheets, or grinding.

The rough crystals are cobbed and freed from adhering quartz, feldspar, or dirt, by rapping with hammers; then they are split with knives or wedges into plates about 1/16 in. or less in thickness. The rough edges are cut off and the plates graded according to size and quality. The

[1] *Min. Res. of U. S.* (1915), p. 289.
[2] See Mineral Industry, **24,** 501 (1915).
[3] *Bull.* 16, Ariz. State Bureau of Mines.

AVERAGE RECORD FROM A NEW HAMPSHIRE MICA MINE

1000 lb. mine-run mica goes to rifters, each rifter handling 200 lb. per day.	400 lb. thumb-trimmed plate goes to cutters.	80 lb. uncleaned stove mica goes to cleaners.	60 lb. finished stove mica @ $1.50 per lb.		$ 90.00
			20 lb. thin split goes to tube makers.	1500 tubes @ $10.00 per M.	15.00
				5 lb. waste goes to grinding.	
		220 lb. waste goes to grinding.			
		100 lb. electric quality plate goes to cleaners.	75 lb. electric plate finished @ 50 cts. per lb.		37.50
			20 lb. thin split goes to tube makers.	1500 tubes @ $10.00 per M.	15.00
				10 lb. waste goes to grinding.	
	50 lb. 2¾-in. washer stock goes to washer cutters.	40 lb. uncleaned washers goes to washer sorters.	30 lb. plate finished washers @ 40 cts. per lb.		12.00
			10 lb. waste goes to grinding.		
		10 lb. waste goes to grinding.			
	60 lb. 1¾-in. washer stock goes to washer cutters.	45 lb. uncleaned washers goes to washer sorters.	35 lb. washers @ 30 cts. per lb.		10.50
			10 lb. waste goes to grinding.		
		15 lb. waste goes to grinders.			
	370 lb. ¾-in. washer stock goes to washer cutters.	92 lb. uncleaned washers goes to washer sorters.	65 lb. washers goes to core department, making 650 cores @ 10 cts.		65.00
			27 lb. waste goes to grinding.		
		278 lb. waste goes to grinding.			
	120 lb. waste goes to grinding.	Total waste, 705 lb.		makes 28 lb. 200–160 mesh @ 2¼ cts.	0.63
				makes 56 lb. 160–120 mesh @ 2 cts.	1.12
				makes 70 lb. 120– 80 mesh @ 1¾ cts.	1.22
				makes 105 lb. 80– 40 mesh @ 1½ cts.	1.57
		Total shrinkage in entire process, 23 lb.		makes 423 lb. 40– 10 mesh @ 1½ cts.	5.34
				Total value	$354.32

material is then ready for further splitting and trimming into desired patterns. Small sheets are commonly left with rough edges and used for making discs, washers, and other forms. Thin "splittings" are also made from small mica. In making these the edges of the plates are beveled and pressed against a flat plate to open the cleavage. The mica is then split with thin knives and the product is built up with shellac cement into mica board and flexible sheets.

Mica is trimmed into forms and patterns by means of large shears and punches. With shears the sheets are cut around templets of wood, metal, or composition. Mica punching machines are supplied with various dies for punching discs, washers, and other shapes. Rough small mica is ground, either wet or dry, according to the uses to which it is to be put. There are several methods, but they are mostly kept secret.

The accompanying flow sheet shows how the product of a New Hampshire mine is handled.

Uses of Mica

Besides a wide application of mica as a non-conductor in the electrical industries, a diminishing, but still important part of the finest sheet muscovite is used for glazing stove and furnace doors, making gas-lamp chimneys and shades, and as reproducing discs in phonographs. These uses demand the best grades and pay the highest prices. Ground mica is used as a lubricant, as an ingredient in vulcanized rubber, as a heat insulator in coverings for steam pipes and boilers, and moulded with shellac or other cement it is made into a variety of forms for electric insulation, under the names micanite, micarta, etc.

The particular value of phlogopite depends on its slightly inferior hardness, as compared with muscovite, rendering it more suitable for insulating strips between commutator bars of dynamos, motors, and magnetos, where the harder muscovite, wearing less rapidly than the metal, is liable to cause sparking.

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MOLYBDENUM

By Alfred W. G. Wilson

The increased demand for molybdenum and molybdenum products, which began a little before the European war in 1914, acted as a stimulus both to prospectors and to producers. Much active prospecting in nearly all the producing areas resulted in the discovery of numerous new prospects, a few of which give promise of future production, and in a temporary over-production of ore. The markets which were available during 1915 were unable to readily absorb all that offered, with the result that there was practically no demand for any considerable quantity of ore at the beginning of 1916. It would appear, however, that experimental work in progress in Allied countries in Europe resulted satisfactorily, because an export demand developed about midsummer, with a consequent stiffening of the price in all free markets, which advances have since been maintained. The demand in the producing areas of the Allied countries has been steady throughout the year, and all lots offering have been purchased for Allied accounts at the fixed market price. The total production of molybdenum ores during the past year has probably been the largest yet attained. It would have been even larger had the authorities authorizing purchases properly understood mining conditions. A marked reluctance to contract for future deliveries of concentrates to be recovered from unmined ores, even with responsible parties in a position to install equipment and begin production, has retarded development, diminished production, and is the cause of the difficulty at present experienced in obtaining all the concentrates required.

The commercial production of molybdenum is obtained either from lead molybdate, wulfenite, containing 26.15 per cent. metallic molybdenum when pure, or from the sulphide, molybdenite, containing 59.95 per cent. metallic molybdenum when pure. Wulfenite is usually bought on the basis of its metallic content or as molybdic oxide, MoO_2. Molybdenite ores are usually purchased on the basis of the molybdenum sulphide, MoS_2, contained, and are the commoner ore. Ferro-molybdenum is usually offered on the basis of its metallic content.

In the United States and Canada the short ton of 2000 lb. is used, and the quotations for molybdenite are based on a unit of 20 lb. In Great Britain and in the principal parts of the British Empire, except Canada, the long ton, 2240 lb., is used and the unit quotation is based on a quantity of 22.4 lb.

In the United States, under the abnormal market conditions caused by the war, market quotations usually represent prices received for sales of small lots, each sale usually being the subject of separate negotiations, and the prices received vary considerably. More recently sales have been arranged for a considerable quantity of concentrates in advance of production.

The quotations for molybdenum ores and concentrates, as reported in the technical press throughout the year, were as follows. During the early months of the year quotations for molybdenite, MoS_2, varied from $1.40 to $1.50 per lb. for a 95 per cent. product. Many quotations varied from $0.60 per lb. for a 50 per cent. product to $1.15 per lb. for a high-grade concentrate. These quotations were maintained during June, July, and August. October sales ranged from $1.50 to $1.80 per lb. for 90 per cent. molybdenum sulphide. These higher prices prevailed during the remaining 2 months of the year. In the last week of December the quotations rose to $2 per lb. Ferro-molybdenum was sold during the first week of November at $4 per lb. for the molybdenum contained, and was also in demand for forward delivery at $3.65 per lb. In December sales took place at $3.80 per lb. and at the end of the month it was quoted at $4, with no spot available, and little future unsold. Some producers are reported to have closed contracts for all their 1917 production. The *Engineering and Mining Journal*[1] quotes 85 per cent. molybdic acid at $3.25 per lb., and 75 per cent. molybdate of ammonia at $2.75 per lb., both moving actively with probabilities of an early advance.

The rise in prices of concentrates and ferro toward the close of the year is supposed to have been due to active competitive buying among domestic and European buyers. The rise in price of molybdic acid and molybdate of ammonia is due to the demands of the steel industries and munition contractors.

Charles Hardy[2] reports that molybdenum ore seems to be becoming more and more a favorite with the ferro-alloy manufacturers, and whereas the sales in this country were made previously to only one or two quarters, there are now a number of manufacturers actually inquiring for and buying molybdenite. New buyers have appeared of late in the New York market; contracts for ferro-molybdenum have been closed to cover the whole of 1917, and if an adequate supply of ore could be guaranteed a further very large quantity could be booked far ahead into 1917.

[1] Jan. 6, 1917.
[2] Quoted by *Eng. Min. Jour.*, Oct. 7, p. 691, and Nov. 4, pp. 847–8 (1916).

In Great Britain the official price of molybdenite has been placed at 105s. per unit, net dry weight, c.i.f. London or Liverpool. Shipments are made at owner's risk and if the ores do not arrive through loss of vessel or for other causes, the contracts with the official consignees become void for such portion as is lost. Messrs. H. A. Watson & Co., K 30 and H 20, Exchange Buildings, Liverpool, have been appointed official purchasers for the United Kingdom. Sales are reported on the British market throughout the year at the official price. Ferro-molybdenum was quoted at 15s. 6d. to 15s. 9d. per lb. for 70-80 per cent. alloy, and sales are reported at the lower figure. No figures are yet available showing the total imports during 1916. Australian exports for the year ending June 30, 1915, included 104 tons of molybdenite, of which 99 tons went to the United Kingdom. It is probable that the receipts during 1916 were in excess of this amount.

In Canada an official price has been fixed in accord with the price in the United Kingdom. The Imperial Munitions Board, Ottawa, acts as agent for the Imperial Government in making all purchases and, for the convenience of Canadian producers, corresponding prices have been arranged f.o.b. railway siding, Mines Branch Testing Laboratories, Ottawa. Payments are calculated on the short ton of 2000 lb., dry weight on assay returns from samples dried at 212° F., the molybdenite, MoS_2, being valued at $1 per lb. The schedules on which payments are made are somewhat detailed.

Molybdenite ores are purchased on the following schedule, a treatment charge of $5.65 per net ton dry weight being deducted:

(*a*) Between 0.50 and 1.0 per cent. for 70 per cent. of the total molybdenite content.
(*b*) Between 1.10 and 1.5 per cent. for 78 per cent. of the total molybdenite content.
(*c*) Between 1.51 and 2.0 per cent. for 84 per cent. of the total molybdenite content.
(*d*) Between 2.10 and 2.5 per cent. for 87 per cent. of the total molybdenite content.
(*e*) Between 2.51 and 3.0 per cent. for 90 per cent. of the total molybdenite content.
(*f*) Between 3.00 per cent. and upward for 92 per cent. of the total molybdenite content.

Payments are made for molybdenite only, no allowances being made for molybdite or wulfenite.

Some Canadian mills are producing a middling product which requires further concentration. Provision has been made to purchase this product on the following schedule—without any additional treatment charge:

(*a*) Between 3.1 and 10 per cent. incl. molybdenite content 83.0 cts. per lb.
(*b*) Between 10.1 and 15 per cent. incl. molybdenite content 85.0 cts. per lb.
(*c*) Between 15.1 and 20 per cent. incl. molybdenite content 87.0 cts. per lb.
(*d*) Between 20.1 and 25 per cent. incl. molybdenite content 88.5 cts. per lb.
(*e*) Between 25.1 and 30 per cent. incl. molybdenite content 90.0 cts. per lb.
(*f*) Between 30.1 and 35 per cent. incl. molybdenite content 91.6 cts. per lb.
(*g*) Between 35.1 and 40 per cent. incl. molybdenite content 92.6 cts. per lb.
(*h*) Between 40.1 and 45 per cent. incl. molybdenite content 93.6 cts. per lb.
(*i*) Between 45.1 and 50 per cent. incl. molybdenite content 94.6 cts. per lb.
(*j*) Between 50.1 and 55 per cent. incl. molybdenite content 95.6 cts. per lb.
(*k*) Between 55.1 and 60 per cent. incl. molybdenite content 96.6 cts. per lb.
(*l*) Between 60.1 and 65 per cent. incl. molybdenite content 97.6 cts. per lb.
(*m*) Between 65.1 and 70 per cent. incl. molybdenite content 98.6 cts. per lb.

Molybdenite concentrates are purchased on the following basis—without treatment charge, prices include cost of delivery to the Mines Branch, in suitable packages for either local or export shipment:

(*a*) Containing not less than 70 per cent. molybdenite for content 1.00 per lb
(*b*) Containing not less than 75 per cent. molybdenite for content 1.02 per lb.
(*c*) Containing not less than 80 per cent. molybdenite for content 1.05 per lb.
(*d*) Containing not less than 85 per cent. molybdenite for content 1.09 per lb.

The International Molybdenum Co., Renfrew, Ont., which operates a custom mill, purchased ores on the following schedule:[1]

Ores containing	2–3	per cent. molybdenite, MoS_2,	$13.00 per unit
Ores containing	3–5	per cent. molybdenite, MoS_2,	14.00 per unit
Ores containing	5–10	per cent. molybdenite, MoS_2,	16.00 per unit
Ores containing	10–15	per cent. molybdenite, MoS_2,	17.00 per unit
Ores containing	15–20	per cent. molybdenite, MoS_2,	18.00 per unit
Ores containing	80	per cent. molybdenite, MoS_2,	1.00 per lb.

Penalties are imposed for bismuth and copper.

The Imperial Munitions Board will purchase ferro-molybdenum containing not less than 70 per cent. molybdenum at $3.25 per lb. for the metal contained. Their specifications place the maximum carbon content at 4 per cent. and sulphur content at 0.4 per cent.

Purchases have been made in the United States and Canada for Allied account. The agents of the French and Italian Governments usually ask for 90 per cent. concentrates. The British and Russian agents have been purchasing both concentrates and ferro-alloy. The ferro-alloy makers are satisfied to purchase ores containing 65 per cent. molybdenite, provided the iron, which is usually present in the form of pyrite or pyrrhotite, does not run above 10 per cent. It is possible to produce a ferro-alloy directly from this ore which will correspond with the British specifications.

Producers estimating the value of their ores c.i.f. docks Liverpool or London must make allowances for the following charges, some of which vary considerably from time to time, and have been advancing steadily: freight to Liverpool or London, master porterage, dock, and town dues and entry, cartage and porterage, half cost of sampling and assay, yard charges and attendance of landing waiter, brokerage at 1 per cent. on market price, petty expenses such as telegrams and postage. These small charges, exclusive of freight, amount to about £6 10s. per long ton. One long ton of 90 per cent. molybdenite, MoS_2, concentrates at 105s. per unit has a gross market value of £472 10s., or $2200 per long ton, when exchange is quoted at $4.70.

Sources and Mining

The occurrence of molybdenum ores has been reported in the following countries, and concentrates in commercial quantities have been pro-

[1] *Min. Sci. Press*, Oct. 14, 1916, p. 578.

duced in most of them: Canada, United States, Bolivia, Peru, Chile, Norway, Sweden, Germany, German East Africa, Rhodesia, Australia (Queensland, New South Wales, Tasmania), New Zealand, and Japan. Owing to war conditions and to restrictions on sales and export, imposed by several producing countries or dominions, accurate data on production, imports, or exports of this commodity are not yet available for 1916.

The Canadian Department of Mines reports shipments from 17 different localities in the Provinces of Quebec, Ontario, and British Columbia. The total molybdenite, MoS_2, contents of the concentrates produced and shipped during the year was 159,000 lb.[1]

The principal Canadian producers during the year were the Canadian Wood Molybdenite Co., operating a mine at Quyon, Que., and owning two concentrating mills in Canada, one at the mine and one at Hull, Que.; the International Molybdenum Co., owning properties near Renfrew, Ont., operating a custom mill at this point, and operating a plant at Orillia, Ont., where their principal products are ferro-molybdenum and molybdic acid; and the Renfrew Molybdenum Mines, Limited, operating a mine and concentrator near Mount St. Patrick, Ont. The Ore Testing Laboratories of the Mines Branch, Department of Mines, Ottawa, belonging to the Federal Government, have been temporarily converted into a custom mill. Custom ores, purchased on behalf of the Imperial Munitions Board, are treated at this plant, and the concentrates are shipped to designated destinations in accordance with the instructions of the Board.

The largest and most important producing mine in Canada, which promises to become one of the largest producers in the world, is that of the Canadian Wood Molybdenite Co. at Quyon, Que. This company made its first shipment in April. Since July 1 the shipments have been at the average rate of about 250 tons per week, the ore containing about 2.5 per cent. molybdenite. The total production for the year was about 5000 tons of ore from which was recovered slightly more than 80 per cent. of the whole Canadian production. A portion of the ore produced was shipped to the Denver plant of the Wood company for treatment; about one-half was treated in the Government plant at Ottawa, and the balance at Renfrew and Quyon. The company's own plants were not ready for operation until near the end of the year.

Development work or exploration has been in progress at a number of points in Canada, and it is expected that several new producers will enter the market during 1917, if the demand for molybdenite still continues. Promising occurrences have been reported from Kawagama lake near Amos in Northern Quebec, from several points in Ontario be-

[1] *Preliminary Report of the Mineral Production of Canada*, 1916, p. 14. Mines Branch, Ottawa.

tween Renfrew and Kingston, from the Molly mine near Salmo, B. C., and from near the head of Alice Arm, north of Prince Rupert.

The occurrences of molybdenum ores in the United States have recently been described by Dr. Frederick W. Horton.[1] Occurrences in six Western and Pacific Coast States are described in considerable detail. These States are Arizona, California, Colorado, Montana, New Mexico, and Washington. Dr. Horton states that these localities contain large low-grade deposits of both molybdenite and wulfenite ores from which considerable tonnages of marketable concentrates might be obtained.

Exports of molybdenite from Bolivia in 1915 totaled 6101 kg., of which Great Britain took 5191 kg. and the United States the remaining 910 kg. The mineral is found in the snow-clad mountains in the Province of Larecaja of the Department of La Plaz. It is expected that further discoveries, which seem very probable, will create a new industry.[2]

Deposits of molybdenite ores, said to be rich, were reported from Peru several years ago. These are located in the Provinces of Jauja and Huancayo in the region of Ricran and Runtaullo, and there are also others in the district of Cascas, Province of Contumaza. The inaccessibility of the mines, most of them being situated at an elevation of 14,000 ft., retarded development until the heavier demand and higher prices were created by the European war. It is stated that not more than 4 tons of 83 per cent. molybdenite concentrates was exported in 1915, and 4.5 tons in 1916. The export duty on this mineral is $4.86 per ton. Samples of ore were on exhibit at the School of Mines in Lama in December, about 6 tons of ore having been brought out by Sr. Eduardo S. Arenas.[3]

The two chief mines in Norway belong to the Knaben and Kvinas companies, and are situated at Knabeheien near the Kvinas valley, north of Flekkefjord. Their combined output of concentrates, averaging 75 per cent. MoS_2, was 72 tons in 1914 and 87 tons in 1915.[4] Since the war began there has been increased prospecting and several new companies have been formed to exploit and develop the surrounding claims. It is therefore to be assumed that the output during 1916 will be in excess of that in previous years. The Knaben-Kvinas deposits are associated with granite and partly granite-gneiss. They appear to some extent in intimate association with massive pegmatite, especially at the boundary of the pegmatite with surrounding granite. In other places one can best speak of molybdenite-bearing quartz-rock, and there are also occurrences

[1] Bureau of Mines, *Bull.* 111, 1916, Molybdenum, Its Ores and Their Concentration.
[2] *Supp. to Comm. Rept.*, Apr. 18, 1917.
[3] *Supp. to Comm. Rept.*, Sept. 12, 1916, and *Comm. Rept.*, Feb. 6, 1917.
[4] H. H. Claudet, *Bull. Can. Min. Inst.*, July, 1916.

of the mineral direct in the granite without any accompanying kind of vein matter; this latter, however, is usually of little extent and seems to be confined to small veins which intersect the granite. The molybdenite zone is extensive, but, so far, there is nothing to prove that the ore will be found at any depth, as all the workings are quite shallow.

The molybdenite usually is finely disseminated throughout the gangue, but at the Knaben mines, where most of the underground work has been done, considerable enrichment is to be noted in places, where rich pockets of large size have been found, sometimes producing massive pieces of molybdenite. In parts of this mine some of the stopes will measure about 10 m. across the lode.[1]

The official report of Swedish mineral production includes 7 tons of molybdenite in 1914 and 37 tons in 1915.

No information is available with respect to the present production of molybdenum ores in Germany or in other parts of the Central Empires. The company operating the Deutsche Molybdänwerke at Teuschenthal, near Halle on the Saale, has enlarged its equipment, and, according to *Zeitschrift für angewandte Chemie*, should be in a position to supply all the requirements of the European steel industry for ferro-molybdenum or molybdenum metal as soon as peace is declared. It is stated further, that the company owns mines producing an abundance of ore.

Molybdenite mineral has been reported from several localities in German East Africa where it occurs disseminated through granite or metamorphic rocks. At Gnasberg, near Hornkranz, it occurs in a pegmatite associated with tourmaline and limonite. At Abib it is found in a reddish granite, both disseminated and massive in schists. From Tsumeb wulfenite associated with copper oxide has been reported.[2] No production is reported as yet.

Molybdenite has been recorded from a number of localities in Rhodesia, but nowhere in any quantity, up to the present time. Specimens have been secured at Glenville, near Bulawayo, from the Antelope mine, and from the Kimberley mine. It has also been reported to occur at the Hay mine and on neighboring properties. More recent discoveries, which are being prospected, have been found near the Umfuli River in the country west of Gatoona. It is also known to occur in the tin fields around Appingendam, where prospecting is in progress.[3]

The mineral molybdenite is also reported from southwest Africa in the vicinity of Walvis Bay, at Usakos, and along the Kuiseb River.

[1] H. H. Claudet, *Bull. Can. Min. Inst.*, July, 1916.
[2] *L'Echo des Mines*, Paris, Sept. 24, 1916.
[3] *So. Afr. Min. Jour.*, Johannesburg, Sept. 2, 1916, and Jan. 20, 1917.

Further south it is reported near Aus and near Warmbad north of the Orange River.[1]

Queensland has been the largest producer of molybdenum ores. In 1915 this production amounted to 97.25 tons, valued at £45,060, which constituted a record as far as values were concerned; in 1916 the output declined to 81 tons. The yield was smaller than that of several previous years; the largest production was 106 tons in 1906. The total production of Queensland to the end of 1915 amounted to 1098.75 tons, valued at £208,097. The percentage molybdenum content of the ores produced is not stated in the reports available. The active demand for molybdenite ores has naturally stimulated prospecting and the Government geologist reports that numerous samples for identification have been submitted by prospectors from numerous localities in the northern, central, and southern coastal districts of the State, and also in the Cloncurry district; but no phenomenal developments have taken place, though a few productive mines have resulted. The principal molybdenite lodes are at Wolfram, in the Chillagoe mining field of northern Queensland, and other important mines occur at Bamford in the same district. Other areas where the mineral is being mined are the Sandy Tate River in the Chillagoe field; Kidston, in the Etheridge Goldfield; Ollera creek near Townsville, in the Star mineral field; at Stanhope near the New South Wales border; and at Khartown in North Queensland. Prospecting was in progress in other areas in the Chillagoe and Herberton mineral fields, and at Rosedale to the northwest of Bundaberg.[2]

New South Wales is also a large producer of molybdenite. The principal operating mines are at Wickhipst in the Pambula division, at Kingsgate in the Glenn Innis division, near Deepwater in the Deepwater division, at Rocky River in the Tantafield division, and in the Bathurst division. Promising prospects at and near Mount Tennyson, near Yetholme were expected to yield additional supplies. In 1914 there were nine mines in operation and the total production was 68.8 tons valued at £11,450; the yield in 1915 was 31.70 tons, valued at £16,937, and in 1916 the output was 54 tons. The total yield to the end of 1915 was 476.15 tons of molybdenite valued at £71,226.

Western Australia and Tasmania are also reported to contain deposits of molybdenite. During the year 1915 Mr. Loftus Hills reported on northeastern and eastern Tasmania, Middlesex and Mount Claude fields.

[1] P. A. Wagner, The Geology and Mineral Industry of South-West Africa, *Geol. Surv. Mem.* No. 7 Union of South Africa.

[2] *Queens. Govt. Min. Jour.*, July 15, 1916, and Jan. 15, 1917. B. Dunstan, Chief Geologist.

His conclusion was that there was one occurrence at Mount Stronach that was worth developing for molybdenite.[1]

Samples of molybdenum-bearing minerals have been reported from New Zealand, an oxide which assayed 50 per cent. MoO_2 being found at Takata.[2]

Occurrences of molybdenum ores are also reported in Chile and Japan. The Japanese production is reported as 24,733 lb. of 40 per cent. ore in 1915, increasing to 74,167 lb. in 1916.[3]

Previous to the European war the principal market for molybdenum ores was Germany, minor quantities being absorbed by other countries, particularly the United States, France, and Great Britain. At the present time the export of molybdenum ores from the countries of origin is in nearly every case either prohibited or restricted.

The production of all parts of the British Empire is controlled by the Minister of Munitions in London. The greater part of the production of the empire is assembled at Liverpool and at London. Restricted export has been permitted to the United States, France, Italy, and Russia. Norway has prohibited the export of molybdenum unwrought or crude. Norwegian concentrates are shipped chiefly to Great Britain and Russia. Japan has prohibited the export of tungsten or molybdenum as from July 29, 1916, except under license granted by the Department of Agriculture and Commerce.

The principal consumers of molybdenum ores in the United States and Canada are:

Baker & Adamson Chemical Co., Easton, Pa.
J. T. Baker Chemical Co., Phillipsburg, N. J.
Electro Metallurgical Co., Niagara Falls, N. Y.
Foote Mineral Co., Philadelphia, Pa.
General Electric Co., Schenectady, N. Y.
Goldschmidt Thermit Co., 90 West St., New York City, N. Y
Grasselli Chemical Co., Cleveland, Ohio.
Imperial Munitions Board, Ottawa, Ont.
International Molybdenum Co., Orillia and Renfrew, Ont.
Pfanstiehl Co., N. Chicago, Ill.
Primos Chemical Co., Primos, Pa.
S. Schaaf-Regelman, New York City, N. Y.
David Taylor, Boston Bldg., Salt Lake City, Utah.
Tivani Steel Co., Belleville, Ont.
Henry E. Wood & Co., Denver, Colo.
York Metal & Alloys Co., York, Pa.

[1] Report of the Secretary of Mines, Hobart Town, Tasmania, 1915.
See also Tungsten and Molybdenum, Parts I and II, by Loftus Hills; Part III, by L. L. Waterhouse, Department of Mines, Tasmania, 1916.
[2] *Min. Eng. World*, Oct. 7, 1916.
[3] *Comm. Rept.*, May 18, 1917.

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MONAZITE

By Joseph Hyde Pratt

The production of monazite in the United States came to a standstill in 1913, and for 2 years there was no production of this mineral reported in this country. Soon after the outbreak of the World War many inquiries were received by the several State Geological Surveys regarding the occurrence of monazite and the owners of properties containing this mineral. It was expected that these inquiries would lead to the re-opening and operation of some of the monazite properties. Up to the present time, however, there has not been any extensive production of monazite in this country. The universal comment of the producers in this country is that they can not compete with the Brazilian monazite.[1] Even the manufacturers of thorium nitrate, who own monazite deposits in this country, intimate that it is more economical to use the Brazilian monazite than to attempt to produce from their own properties. The large increase in price of thorium nitrate was also expected to have an influence on the production of monazite in this country, but up to the present time that has only been felt to a limited extent.

While the price of thorium nitrate, which was formerly imported in large quantities from Germany, has continued to advance, there has not been any corresponding increase in the price of monazite. During the past 7 years the selling price of thorium nitrate in the United States has increased from $2.85 to $8.50 per lb., and monazite sand has varied from 8 to 12 cts. per lb. during the same period. This high price of thorium nitrate has caused several firms to take under consideration the manufacture of this chemical compound, and they are investigating sources of monazite in this country. For the past several years there has been a small production of monazite in the United States, and while the production is very small as compared with the imports, yet it is indicative that the monazite deposits of this country may be operated in competition with the Brazilian deposits.

The mineral thorite,[2] and also silicate of thorium ($ThSiO_4$) has been found in commercial quantity in Ceylon, and is being mined to some

[1] The Brazilian monazite deposits were briefly described in Mineral Industry, **24**, 510.
[2] *Bull.* 25, N. C. Geol., and Econ. Surv., 1916, p. 29.

extent, and imported into this country. This mineral has been found sparingly in the United States; at one locality in New York[1] and in the granite of the Trotter Mine,[2] Franklin Furnace, N. J. The general occurrence of this mineral seems to be in pegmatite or granitic rocks. With the importation of this mineral from Ceylon, the American monazite has another competitor as a source of thorium. The Brazilian output of monazite was formerly shipped almost entirely to Germany, and the thorium nitrate manufactured from its thoria content was shipped in quantity to this country. As stated in the 1916 report, the big cut in the price of thorium nitrate in 1906 made it possible for the users of thorium nitrate in this country, as well as the manufacturers, to buy thorium nitrate from Germany cheaper than they could manufacture it from American monazite. With the advent of the World War, however, more of the Brazilian monazite has been shipped to the United States.

The monazite in Brazil and the Carolinas of the United States is limited, and is in fact not very extensive, and thus any new occurrences of monazite become of considerable interest.

New Occurrences of Monazite

During the past year two new occurrences have been reported.

1. In the Transvaal[3] in the Pretoria district to the northeast of the City of Pretoria. This occurrence is reported as distinguished from the Houtenbeck occurrence which has been known for some time.

2. The other occurrence reported was from German Africa near Keidoius, where monazite is reported to have been found in a muscovite pegmatite.

Nothing definite is reported in regard to whether or not these two localities are likely to become producers of monazite.

Price of Thorium Nitrate

In order to show the variation in the price of thorium nitrate, and how the break in price in 1906 continued for nearly 8 years, reaching its lowest ebb in 1914, and then with the outbreak of the war, the rapid advance in price until it reached its highest figure during the past few months, there is given in the following table the prices of thorium nitrate for the years 1894 to 1917:

[1] Dana, "Mineralogy," Sixth Edition, p. 489, 1892.
[2] *Trans. New York Academy of Science*, **13**, 76, 1893.
[3] *So. Afr. Min. Jour.*, April 22, 1912, p. 7.

PRICES OF THORIUM NITRATE, 1894–1917

Year.	Price of Thorium Nitrate. Europe (per Kilo).	Price of Thorium Nitrate. United States (per Pound).(*a*)
	Marks.	Dollars.
1894	2000	......
1895, January	900	......
1895, July	500	......
1895, November	300	......
1896, early part	150	......
1896, latter part	96	......
1897	60	......
1898	40	......
1899	30	......
1900	28	......
1902	36	......
1903	43	5.86
1904, early part	43	5.86
1904, latter part	43	6.10
1905	43	6.53
1906	27	3.78
1907, early part	32	3.93
1907, latter part	32	4.65
1908	32	4.70
1909	27	3.87
1910, early part	19	3.20
1910, latter part	17	3.00
1911	22	3.00
1912	22	3.00
1913, early part	21	2.85
1913, latter part	21	2.60
1914, early part	22	2.71
1914, latter part	22	3.25
1915, early part	......	4.00–4.50
1915, latter part	......	5.25–6.00
1916, early part	......	6.35–7.25
1916, July–October	......	6.50–7.00
1916, October–January, 1917	......	7.00–7.50
1917, January–April	......	8.00–8.50

(*a*) Data furnished by Dr. Hugo Lieber, 25 Madison Avenue, New York, N. Y.

Production

During the past year monazite has been produced in North Carolina in Burke, Cleveland, Iredell, Lincoln, and Rutherford Counties. The

MONAZITE PRODUCTION IN THE UNITED STATES

Year.	United States. (*a*) Pounds.	United States. (*a*) Value.	United States. (*a*) Per Pound.	North Carolina. (*b*) Pounds.	North Carolina. (*b*) Value.	North Carolina. (*b*) Per Pound.
1905	1,352,418	$163,908	$0.121	894,368	$107,324	$0.120
1906	846,175	152,312	0.180	697,275	125,510	0.180
1907	547,948	65,754	0.120	(*c*)456,863	54,824	0.120
1908	422,646	50,718	0.120	(*c*)310,196	37,224	0.120
1909	541,931	65,032	0.120	(*c*)391,068	46,928	0.120
1910	99,301	12,006	0.121	83,454	10,104	0.121
1911	3,561	427	0.120	400	48	0.120
1912	1,272	159	0.120	*Nil.*	......	......
1913	*Nil.*	......	......	*Nil.*	......	......
1914	*Nil.*	......	......	*Nil.*	......	......
1915	(*d*)	......	......	(*d*)	......	......
1916	76,872	6,241	0.081	76,872	6,241	0.081

(*a*) Statistics are those of the U. S. Geological Survey. (*b*) Statistics for N. C. from 1893 to 1902 are estimates; those from 1903 to 1906 are from "The Mineral Industry of North Carolina;" those for 1910 are furnished by Joseph Hyde Pratt, State Geologist. (*c*) Statistics for 1907, 1908, and 1909 were collected jointly by the U. S. Geological Survey and the N. C. Geological and Economic Survey. (*d*) As there was only one producer in 1915, statistics can not be given.

production was not large, and amounted to 76,872 lb., valued at $6241. Its value varied from 7½ to 12 cts. per lb., according to the purity of the concentrates. The concentrates sold varied from 50 to 70 per cent. monazite.

There is given in the foregoing table the production of monazite in the United States for the years 1905–1916 inclusive.

Imports

The imports of monazite sand and thorite in 1916 amounted to 1,221,-399 lb., valued at $120,077.00, or $0.098 per lb.

The thorium nitrate imported into the United States during 1916 was only 909 lb., valued at $3,884.00, or $4.27 per lb.

There is given in the following table imports of thorium nitrate and monazite sand and thorite:

IMPORTS OF THORIUM NITRATE AND MONAZITE (a)

	Year.	Pounds.	Value.	Per Pound.
Thorium nitrate entered for consumption..........	1910	108,597	$218,713	$2.01
	1911	121,111	238,841	1.97
	1912	117,485	225,386	1.92
	1913	112,105	212,263	1.89
	1914	101,927	239,376	2.35
	1915	67,406	169,617	2.52
	1916	909	3,884	4.27
Monazite sand (and thorite) entered for consumption.	1910	453,554	$39,699	$0.0875
	1911	705,149	60,542	0.086
	1912	556,959	47,334	0.085
	1913	1,145,010	94,425	0.082
	1914	770,842	61,595	0.080
	1915	1,873,971	161,456	0.117
	1916	1,221,399	120,077	0.098

(a) Bureau of Statistics of the Department of Commerce and Labor.

NICKEL AND COBALT

By O. C. von Schlichten

United States.—No ores are mined in the United States for their nickel content, though a few hundred tons are annually obtained as a by-product from copper ores. The United States is the largest producer of nickel, but the raw material is obtained chiefly from Canada. More nickel was produced in 1916 than in any previous year, the 1915 production being exceeded by about 32 per cent., due to the great demand created by the war.

The imports of nickel for 1916 are given as 72,611,492 lb. contained in ore and matte, and were valued at $9,889,122, representing an average value of 13.62 cts. per lb. Exports for 1916 were 33,404,011 lb., valued at $12,952,493, or 38.775 cts. per lb. Imports for 1915 and 1914 were 56,352,582 and 35,006,770 lb. respectively, while the exports for the same periods were 26,418,550 and 27,595,152 lb.

Statistics for the past few years, together with destination of exports, are given in the table below.

Year.	Imports.							Exports.	
	Nickel Ore and Matte.		Nickel Alloys. (*a*)		Nickel Mnfrs.	Cobalt Oxide.		Nickel. (*b*)	
	Long Tons.	Value.	Pounds.	Value.	Value.	Pounds.	Value.	Pounds.	Value.
1902.	14,817	$1,156,372	752,630	$251,149	$30,128	79,984	$151,115	3,228,607	$925,579
1903.	15,936	1,285,935	521,344	170,670	37,284	73,350	145,264	2,414,499	703,550
1904.	8,548	915,470	589,555	203,071	2,950	42,352	86,925	7,519,206	2,130,933
1905.	13,451	1,626,920	941,966	331,920	3,291	70,048	139,377	9,550,918	2,894,700
1906.	15,156	1,816,631	210,000	77,373	8,963	41,084	83,167	10,620,410	3,493,643
1907.	(*d*)16,888	2,153,873	180,025	80,994	9,159	48,013	74,849	8,772,578	2,845,663
1908.	(*e*)16,322	2,396,217	241,868	91,388	10,010	219,098	17,077	9,770,248	3,297,988
1909.	(*f*)18,578	2,927,975	277,911	104,019	4,279	12,132	11,096	12,048,737	4,101,976
1910.	(*g*)28,519	4,085,076	323,239	125,013	14,759	6,124	4,806	15,244,937	4,704,088
1911.	(*h*)23,993	3,918,556	293,301	104,160	.....	14,561	7,576	25,099,586	8,283,777
1912.	(*i*)33,101	5,638,456	(*j*)223,168	103,300	17,203	31,848	15,132	25,815,016	8,515,332
1913.	(*k*)37,623	6,427,639	336,590	133,917	37,200	47,277	26,154	29,173,088	9,686,794
1914.	29,564	4,956,448	109,213	45,146	13,010	227,886	220,593	27,595,152	9,455,528
1915.	45,798	7,615,999	32,487	13,687	6,242	154,672	148,828	26,418,550	10,038,514
1916.	59,741	9,889,122	29,917	7,869	25,880	206,639	192,009	33,404,011	12,952,493

(*a*) Includes nickel oxide, and alloys of any kind in which nickel is the material of chief value, in ingots, bars, and sheets. (*b*) Comprises domestic nickel, nickel oxide, and matte. (*d*) Contained 18,418,305 lb. nickel; not reported previous to 1907. (*e*) Contained 16,586,423 lb. nickel. (*f*) Contained 21,916,182 lb. nickel. (*g*) Contained 32,050,032 lb. nickel. (*h*) Contained 29,545,967 lb. nickel. (*i*) Contained 42,168,769 lb. nickel. (*j*) Weight of nickel alloys only, value $85,059. (*k*) Contained 47,194,101 lb. nickel.

Exports of Nickel from United States, Pounds	1913.	1914.	1915.	1916.
To France	3,631,858	3,457,157	3,018,354	2,283,132
To Italy	....	....	....	2,715,521
To Netherlands	6,622,811	855,168	129,557	516,331
To Russia in Europe	....	....	....	7,767,875
To United Kingdom	8,221,640	10,836,369	14,801,565	16,674,487
To other countries	10,096,779	12,446,458	8,469,074	2,906,665
Total	29,173,088	27,595,152	26,418,550	33,404,011

Total exports for 1916 were 33,404,011 lb., or considerably less than half the quantity imported. These figures do not take into account, however, the vast amount of nickel exported in the form of nickel steel, etc., for war purposes. Large exports to Italy and Russia in Europe have been made for the first time. A little more than half of all the exports went to the United Kingdom.

Considerable agitation was created in Canada by the export of some nickel to Germany by the submarine *Deutschland*, as it was believed that Canada was indirectly supplying the enemy with this important metal. So great, indeed, was the agitation that the Minister of Mines published a statement asserting positively that no Canadian nickel was carried by the *Deutschland*, but that the metal was by-product nickel from American ores and was purchased by German agents in small lots. The agitation, however, gave considerable impetus to the demand for the construction of a nickel refinery in Canada.

The International Nickel Co. owns large nickel deposits at Sudbury, Ont., with estimated reserves of about 57,000,000 tons of ore. It also owns large deposits in New Caledonia. The fiscal year ended Mar. 31, 1917, was the most profitable one in the history of the company. Earnings applicable to the 1,673,384 shares of common stock were $13,023,214, compared with $11,748,278 in the preceding year. While other metals have advanced greatly in price, nickel has advanced but slightly, so that the increase in earnings was brought about by finding new uses for the metal, increased consumption by automobile makers and manufacturers of certain war materials.

Considerable money was expended by the company during the past year for additional property, construction and equipment. In the annual report it is stated that the refinery at Port Colborne, Ont., will cost $5,000,000 and that it will be ready for operation by the beginning of 1918. The property is located at the Lake Erie entrance of the Welland Canal and is considered the best point in Canada for assembling materials. Up to the close of the year, the actual expenditure on this construction has been $1,046,740. Construction is proceeding at a rapid pace, considering difficulties in securing both labor and materials.

Canada.[1]—The production of nickel in 1916 has, as usual, been derived from the ores of the Sudbury district supplemented by the recovery of a small quantity of metallic nickel, nickel oxide and other nickel salts as by-products in the treatment of ores from the silver-cobalt-nickel ores of the Cobalt district.

The total production was 82,958,564 lb. which at 35 cts. per lb. would have a total value of $29,035,497. The total production in 1915 was 68,308,657 lb., showing an increase in 1916 of 14,649,907 lb., or 21.5 per cent.

The nickel-copper ores, derived from nine separate mines in the Sudbury district, supplemented by a small tonnage of similar ores from the Alexo mine in Timiskaming, is reduced in smelters and converters at Copper Cliff and Conniston to a Bessemer matte containing from 77 to 82 per cent. of the combined metals and shipped in that form to Great Britain and the United States for refining, the product of the Canadian Copper Co. going to New Jersey and that of the Mond Nickel Co. to Wales. A refinery is now under construction at Port Colborne, Ont., by the International Nickel Co., in which a portion of the matte produced by the Canadian Copper Co. will be refined.

Although not shipping during the year the British-American Nickel Corporation, Ltd., has been actively engaged in the development of its nickel properties in the Sudbury District and in the erection of a smelter.

The total production of matte in 1916 was 80,010 tons, containing 44,859,321 lb. of copper and 82,956,862 lb. of nickel. The tonnage of the ore smelted (part being previously roasted) was 1,521,689 tons. The production in 1915 was 67,703 tons of matte containing 39,216,165 lb. of copper and 68,077,823 lb. of nickel.

Nickel was recovered as a by-product in smelters at Deloro, Thorold and Welland, from the silver-cobalt-nickel ores of the Cobalt district, the total nickel contents of nickel oxide, nickel sulphate and metallic nickel produced being 361,701 lb. The products recovered included 79,360 lb. of metallic nickel; 323,418 lb. of nickel oxide and 232,450 lb. of nickel sulphate, having a total reported value of $132,896. The recovery from these ores in 1914 was 231,634 lb. of nickel.

The exports of nickel in ore, matte and other forms are reported by the customs department at 80,441,700 lb. valued at $8,622,179, or an average of 10.77 cts. per lb., of which about 83 per cent. was exported to the United States.

The following table shows the production of nickel by smelters in the Sudbury districts and the exports from Canada.

[1] *Preliminary Report of the Mineral Production of Canada,* Can. Dept. Mines.

CANADIAN PRODUCTION AND EXPORT

(From Preliminary Report, Mineral Production of Canada—1916)

	1912.	1913.	1914.	1915.	1916.
Ore mined	737,584	784,697	1,000,364	1,364,048	1,566,333
Ore smelted	725,065	823,403	947,053	1,272,283	1,521,689
Bessemer matte produced	41,925	47,150	46,396	67,703	80,010
Copper content of matte	11,116	12,938	14,448	19,608	220,450
Nickel content of matte	22,421	24,838	22,759	34,039	41,298
Spot value of matte	$6,303,102	$7,076,945	$7,189,031	$10,352,344	....

	Lb., 1912.	Lb., 1913.	Lb., 1914.	Lb., 1915.	Lb., 1916.
Nickel contained in matte, etc.:					
Exported to Great Britain.	5,072,867	5,164,512	10,291,979	13,748,000	11,136,900
Exported to United States.	39,148,993	44,224,119	36,015,642	52,662,400	69,304,800
Exported to other countries	....	70,386	220,706	....	....
	44,221,860	49,459,017	46,538,327	66,410,400	80,441,700

There has been considerable agitation in Canada for the construction of nickel refining plants in Ontario and this has been very much augmented by the exportation of a small quantity of nickel to Germany. The International Nickel Co. was the target of most of the agitation, as it was believed by many that Germany obtained her cargo of nickel through this company. On Sept. 9, 1915, a commission of four experts was appointed to investigate the resources, industries and capacities of Ontario in connection with nickel and its ores. A summary of the report of this commission appeared in the April issue of the *Canadian Mining Journal*, 1917. The Commissioners are of the opinion that:

"1. The nickel ore deposits of Ontario are much more extensive and offer better facilities for the production of nickel at a low cost than do those of any other country. Nickel-bearing ores occur in many parts of the world, but the great extent of the deposits in this Province, their richness and uniformity in metal contents, and the success of the industry point strongly to the conclusion that Ontario nickel has little to fear from competition.

"2. Any of the processes now in use for refining nickel could be successfully used in Ontario, and conditions and facilities are at least as good in this Province as in any other part of Canada.

"3. In view of the fact that practically no chemicals are required, that there is a much more complete saving of the precious metals, especially platinum and palladium, and that electric power is cheap and abundant, the most satisfactory method of refining in Ontario will be the electrolytic.

"4. The refining of nickel in Ontario will not only benefit the nickel industry, but will promote the welfare of existing branches of the chemical and metallurgical industries, and lead to the introduction of others.

"5. The methods employed at the Ontario plants of the two operating nickel companies are modern and efficient, although there are differences in both mining and smelting practice. It is the consistent policy of both companies to adopt all modern improvements in plant or treatment. Even during the present time of acute pressure the Canadian Copper Co. has materially increased its output without substantial enlargement of its plant, and the losses in smelting are less, both at Copper Cliff and the Mond plant at Conniston, than they were a year ago. These companies have each had their experimental stage, neither has asked nor received any government assistance, and both have earned the success which they have achieved.

"6. The present system of mining taxation is just and equitable and in the public interest, and is the best system for this Province. Any question of change is rather one of rate than of principle.

"7. Experiments have been undertaken by the commission in the production of nickel-copper-steel direct from Sudbury ores, and also in the electrolytic refining of nickel. Certain improvements in the latter process have been made the subject of application on behalf of the Government of Ontario for patents in Canada, United States and Great Britain."

The Commission further states that, "the proven or positive ore of the Sudbury area can be conservatively put at 70 million tons, while it is safe to say that the proven, together with the probable and possible ore supply, exceeds 150 million tons. The International Nickel Co.'s published estimate of their ore reserves is 57 million tons, which is for three mines only. Although the Sudbury deposits have been worked for 29 years, there is vastly more ore proven in the district to-day than there was 5 years ago.

"No such vast deposits of workable ores, considered as a source of metallic nickel, are known in any other country, and there is no reason to believe that any competition will arise with which Ontario can not cope."

There are three standard methods of refining nickel from ores of the Sudbury type: (1) the Orford process, (2) the Mond process and (3) the electrolytic or Hybinette process.

In the Orford process the copper-nickel matte is smelted with sodium sulphate and carbonaceous matter, producing a double sulphide of copper and sodium which separates as an upper layer above a matte much richer in nickel and poorer in copper. A repetition of this process eliminates the bulk of the copper and a matte is finally obtained that is so rich in nickel that, after being roasted and leached, it can be smelted in a reverberatory furnace for the production of metallic nickel.

The disadvantage of the Orford process is that there is but a small recovery of the precious metals and it is believed that the loss of copper and nickel is greater than in the other two processes.

In the Mond process the ores are roasted to remove the sulphur, and leached with sulphuric acid to remove the copper as copper sulphate, followed by the reduction of nickel oxide together with a small quantity of copper oxide by means of producer gas to a finely divided metallic state. Next the metal is treated in a vertical chamber at a certain temperature with producer gas, which converts the nickel into the volatile nickel carbonyl, which in turn is decomposed to metallic nickel in another tower at a still higher temperature.

The Hybinette process will be employed by the British American Nickel Corporation in Ontario. The nickel is deposited electrolytically, the soluble anodes being partly roasted nickel-copper matte. The copper obtained in this process is cast into anodes and is then electrolytically purified.

The Province of Ontario is peculiarly adapted to this process as it possesses an abundance of water power through which an abundance of electric energy may be produced. The absence of coal deposits make this a most important feature. The electrolytic process also possesses the great advantage that the plant may be quickly erected and as many units may be quickly added as an increase in output may demand.

The price of nickel has been slightly advanced during the year. In May, 1916, the British Government was obtaining all its supplies from four companies at 38.8 cts. per lb., but the ruling price in England at that time was about 49 cts. per lb. Prior to the war the British Government was paying 34.8 cts. per lb.

Other Countries.—The New Caledonian mines have been operated for about 40 years and during this time about 160,000 tons of metal has been produced from this source. This amount is approximately equal to 4 years' production from the Sudbury district. The estimated reserves of the New Caledonian mines is supposed to equal the amount already taken out. The annual report of the Mines Department for 1916 states that the Societé Le Nickel exported from New Caledonia during the year 30,000 tons of nickel ore and 2400 tons of 45 per cent. matte. The Societé des Hauts Fourneaux exported 3000 tons of ore and 3350 tons of matte.

An important nickel discovery appears to have been made in San Diego County, California, as reported by F. C. Calkins of the U. S. Geological Survey. The origin of the ore appears to be similar to the Sudbury deposits. The deposit occurs as an irregular mass in a dark gabbro. Assays of more than 4 per cent. nickel, and copper from a trace up to 2.4 per cent. have been obtained. Platinum may also be present.[1]

Nickel, chromium and iron ore discoveries have been reported to occur in Silesia, Germany. The ore was discovered several years ago, but lack of railroad facilities has prevented their exploitation. A new railway line has been projected and this has renewed the interest in the deposits.[2]

It has also been reported that nickel ore has been found in the district of Orivio, Bolivia.

The Evje Nickel Refinery, near Christiansand, Norway, has been destroyed by fire. Norway in 1914 (no later returns are available), produced about 800 tons of nickel, and it is stated that the entire output of the country has been going to Germany. Early in 1915 Norway placed an embargo upon the export of nickel ores and unwrought nickel, except that produced by Norwegian works.[3]

Technology.—Investigations carried on at the University of Toronto by Professor H. E. T. Haultain and Mr. F. C. Dyer have shown that nickel and copper minerals can be readily separated by flotation.[4] A concentrate containing about 25 per cent. copper and very little nickel is floated off, while the minerals pentlandite and pyrrhotite sink together. The nickel concentrate contains but little copper. The iron coming down with the nickel, a product is obtained which might be used for the direct production of nickel steel. This flotation process is unique in that no oils nor acids are used.

U. S. Patent 1,185,187 has been taken out by Frederick A. Eustis, of Milton, Mass. and Charles P. Perrin, of New York for a process for the direct production of iron-nickel alloys.[5] Iron ores containing a small amount of nickel, such as the Cuban ores, are divided into two parts. One part, which is to be treated for the extraction of the nickel, is roasted with a sulphur-bearing material and nickel sulphate is leached from the product. Metallic nickel is precipitated and the precipitate is added to the other part of the iron ore in the desired amount.

A new nickel-iron alloy, containing 13 per cent. nickel and 0.55 per cent. carbon was recently discovered by J. O. Arnold and A. A. Read. It is so hard as to be unmachinable and the investigators were unable to obtain drillings for analysis. The yield point is about 134,000 lb. per sq. in. and the tensile strength is about 195,000 lb., with a 12 per cent. elongation in 2 in.[6]

[1] *Eng. Min. Jour.*, Aug. 12, 1916.
[2] *Comm. Rept.*, Feb. 17, 1917.
[3] *Metal. Bull.*, May 11, 1917.
[4] *Can. Min. Jour.*, Aug. 15, 1915.
[5] *Eng. Min. Jour.*, Oct. 7, 1916.
[6] *Can. Min. Jour.*, Aug. 15, 1916.

Cobalt

The total production of cobalt during 1916 is estimated at 841,859 lb. and was valued at $926,045.[1] The 1915 production was equivalent to 504,212 lb. valued at $536,268.

Cobalt is recovered at the smelters at Deloro, Thorold and Welland, Ont. The 1916 production included 215,215 lb. of metallic cobalt, 670,760 lb. of cobalt oxide and smaller quantities of cobalt sulphate, carbonate hydroxide, unseparated oxides, stellite and cobalt residues.

The 1915 production included 211,610 lb. of metallic cobalt and 423,717 lb. of cobalt oxide and sulphate.

The price of cobalt during 1916 was quoted at from $1.25 to $1.50 per lb.

A few years ago practically the only use for cobalt was the production of the blue color in the glass and ceramic industries and in a small way for the production of a blue paint. These industries consumed but 300 or 400 tons of cobalt per year.

New uses for metallic cobalt are being found, however, and it is said to possess several advantages over nickel for electroplating. A greater resistance to abrasion is obtained with a smaller quantity of the metal and the plating is accomplished more rapidly if the proper bath is used.

The Canadian Department of Mines carried out extensive experiments in electroplating with cobalt.[2] The two most successful electrolytes are made as follows:

I B (Serial Number)

$CoSO_4(NH_4)_2SO_4$	200	grams
Water	1000	grams

XIII B (Serial Number)

$CoSO_4$	312.5	grams
NaCl	19.0	grams
Nearly saturated solution of boric acid	1000.0	c.c.

These solutions were tried out practically by the Russell Motor Car Co., of Toronto. Articles of copper, brass, iron, steel, tin, German silver, lead, and Britannia metal were plated under the same conditions that obtain during electroplating of nickel. Excellent deposits were obtained with a current density of 244 amp. per sq. ft., and a 3-min. immersion in the plating bath gave a deposit on articles that required 1 hr. immersion in the nickel bath. The cobalt deposits withstood all the tests usually applied to nickel deposits and it was found to be harder and more ductile than the latter.

Experiments on non-corrosive iron-cobalt alloys were carried out by

[1] *Preliminary Report of the Mineral Production of Canada for* 1916, Dept. Mines.
[2] *Min. Sci. Press*, June 24, 1916.

Herbert T. Kalmus and K. B. Blake at Queens University.[1] They determined that the addition of 0.25 to 3 per cent. of copper, nickel, or cobalt to ingot iron greatly increases the resistance to corrosion, since a protective coating of oxide film is formed as corrosion advances. The coating produced when cobalt is present is darker, denser and more tenacious than that produced with alloys of copper or nickel. The percentage of carbon in the alloy determines the amount of corrosion. Tests are being conducted with the alloys mentioned above by corroding to destruction.

[1] *Min. Sci. Press*, Mar. 10, 1917.

PETROLEUM AND NATURAL GAS

By David T. Day

The events in the production of petroleum in the United States during 1916 gave an interest to the entire industry beyond even the sensational features which characterized 1914 and 1915. The matters of chief interest in the year 1916 were in sharp contrast with the exciting events of 1914 and 1915. During the earlier period sensational discoveries of new oil fields, particularly the Cushing pool, demoralized the trade by the resulting surplus of oil, and, as shown in the previous report of this series, the effects were felt far into foreign countries. In 1916, on the contrary, equally keen interest was aroused by a decline in stocks and increased market demands. The resultant stimulus in prices kept the production up to the high limit of the year before with only a very slight increase in the total.

The history of the sudden increments in the supply of oil has shown the necessity for guarding against an equally sudden decline of this gusher production. At the beginning of 1916 the consumers were sharply on the watch for such a decline in the Cushing field as would lead to drawing on stocks. This came in the month of November. Since that time to the end of the year, and on into 1917, drawing on stocks, with the consequent rise in price for all grades of oil, has placed the oil interests in the front rank with even war materials in the attention paid to oil-stock investment, and has led to an unprecedented search for new oil fields.

The resultant discoveries of new fields have been practically negligible, but increased production has been secured in Oklahoma, Kansas and in Wyoming. It should be noticed that this has been brought about by a different campaign in the search of oil fields than has been previously in vogue. This is set forth in a statement contributed by Mr. Dorsey Hager on another page.

Considering the States in detail, the great production came from the Mid-Continent field, which totaled 128,085,506 bbl. for the year, according to the best estimate which can be made at this time. An increase was made in production in Kansas, and also a potential increase in the developments under the geological guidance of Mr. Carpenter, acting for the Empire Oil & Gas Co., in the Augusta and Eldorado pools.

Figures compiled by the *Oil and Gas Journal* on the petroleum production of the United States for 1916 indicate that the amount obtained was 303,495,292 bbl. Compared with the 301,872,208 bbl. produced in 1915, that for 1916 showed an increase of 1,623,084 bbl. The *Journal* points out that this increase does not agree with the report of the United States Geological Survey, which gave an increase of over 11,000,000 bbl., but it must be noted that the latter refers more particularly to the respective amounts marketed in the 2 years, rather than the actual output.

The following tables gives the production for the various divisions for 1916 compared with 1915, in barrels of 42 gal.:

	1915.	1916.
Penna. W. Va., N. Y. and S. E. Ohio	20,333,480	20,724,836
Lima-Indiana	3,979,467	2,606,831
Illinois	15,588,493	16,349,274
Kentucky	479,366	1,244,752
Kansas	4,009,329	13,042,800
Oklahoma	117,910,444	106,190,240
North Texas	5,591,422	8,852,865
Louisiana	15,940,393	11,862,466
Gulf Coast	22,906,779	23,921,866
California	89,768,298	91,822,362
Wyoming	5,164,737	6,672,000
Miscellaneous	200,000	205,000
Total	301,872,208	303,495,292

Below is given the U. S. Geological Survey table of the marketed production of petroleum in 1915 by States and an estimate of the production in 1916 in barrels of 42 gal. each:

	1915.	1916.
Oklahoma	97,915,243	105,000,000
California	86,591,535	89,000,000
Texas	24,942,701	26,000,000
Illinois	19,041,695	16,500,000
Louisiana	18,191,539	15,800,000
West Virginia	9,264,798	8,500,000
Pennsylvania	7,838,705	8,000,000
Ohio	7,825,326	7,400,000
Kansas	2,823,487	6,500,000
Wyoming-Mont	4,245,525	6,300,000
Kentucky	437,274	1,200,000
Indiana	875,758	1,000,000
New York	887,778	900,000
Colorado	208,475	190,000
Other States	14,265	10,000
Total	281,104,104	292,300,000

Oil Exports for 1916.—The quantity and value of petroleum products exported from the United States in 1916 increased over the amount and value in 1915 and 1914. The total gain in quantity for all products for 1916 was nearly 12 per cent. over 1915, but the gain in value amounted to 41 per cent. Among the products the greatest gain was shown by naphtha products, which consist chiefly of gasoline. The gain was 26 per cent. in quantity as measured in gallons, and 102.4 per cent. in its value. Even lubricating oils, the export of which is necessarily steadier than any other petroleum product, increased nearly 9 per cent. in quantity, and with the general increase in prices its total value showed an increase of 326 per cent. As compared with the last normal year, that is previous to the war, the general increase in petroleum exports amounted to 22 per cent. in quantity and 35 per cent. in value, the principal gain being in gasoline, the details of which are shown in the table following:

1916 MINERAL OIL EXPORTS AND COMPARISONS[1]

	1916		1915		1914	
	Gallons.	Values.	Gallons.	Values.	Gallons.	Values.
Crude	172,029,903	$7,030,923	158,263,069	$4,282,827	124,735,553	$4,958,838
Illuminating	854,403,313	55,845,103	836,998,731	49,947,273	1,010,449,253	64,112,722
Lubricating	260,779,127	43,022,468	239,719,488	32,441,794	191,647,570	26,316,313
Gasoline	167,928,262	33,614,957	112,560,475	13,162,990	162,669,038	19,897,613
Other naphthas	188,288,863	35,055,589	169,770,999	20,762,599	47,023,617	5,390,801
Gas and fuel oil	957,518,417	27,002,087	799,646,143	22,010,458	634,298,844	18,019,333
Residuum	6,543,324	161,436	12,616,712	364,381	69,209,777	1,204,917
	2,607,491,209	$201,732,563	2,329,575,617	$142,972,322	2,240,033,652	$139,900,587

Petroleum Age, 1917.

Petroleum Shales

The U. S. Geological Survey offers the following figures as to the prospective crude oil supply, as of Jan. 1, 1917.

	Estimated Percentage of Total Oil Content Exhaustion.	Remaining Supply in Millions of Barrels.
Appalachian	70	481
Lima-Indiana	93	31
Illinois	51	244
Mid-Continent	25	1,874
North Texas	8	484
Northwest Louisiana	22	124
Gulf	13	1,500
Colorado	65	6
Wyoming-Montana	2	540
California	26	2,345
		7,629

The obvious limits to the duration of the petroleum supply of the United States indicated by these figures, when considered with even the present rate of production, give great interest to a study of the petroleum shales of the United States, especially those occurring in large quantities in the Western States. The bulletin of Woodruff and Day, published by the Geological Survey several years ago, showed that the petroleum shales of the Uinta Basin, in western Colorado and eastern Utah, were capable of yielding perhaps four times as much petroleum as all the known oil fields in the United States together, and considering in this estimate only such shales as were about twice as rich as the successful Scotch petroleum shales.

The activity of the U. S. Geological Survey and the Bureau of Mines in investigating the oil shales on public lands, especially in western Colorado and eastern Utah, has led to much information concerning available acreage of oil shales in the Uinta Basin and the amount of oil per ton which can be obtained in various sections in that region. The considerable amount of information obtained, especially in *Bulletin* 641-F of the U. S. Geological Survey, by Dean Winchester, has aroused much interest, and has resulted in the patenting of considerable shale areas and withdrawal by the Interior Department of a large area for the future needs of the United States Navy. The U. S. Geological Survey has made the following statement concerning this work:

"During the last year a large area of land in Colorado, Utah, and Wyoming has been classified by the Department of the Interior as mineral land valuable for oil shale. The lands so classified, except two small areas, one each in Colorado and Utah, which have been set aside as naval oil-shale reserves, are open to mineral entry under the mining laws of the United States and to non-mineral entry in accordance with the provisions of the Act of July 17, 1914, the oil-shale deposits when entries are made under this act being reserved for separate acquisition under the mineral land laws.

"In Colorado the naval oil-shale reserve comprises lands in Tps. 5 and 6 S., Rs. 94 and 95 W., sixth principal meridian, having a total acreage of 45,440 acres, whereas the total area classified as oil-shale land in this State includes about 896,000 acres. In Utah the naval oil-shale reserve includes lands in Tps. 12 and 13 S., Rs. 18 and 19 W., having a total area of 86,584 acres, whereas the area classified as oil-shale land includes approximately 2,636,000 acres. In Wyoming approximately 460,000 acres have been classified as oil-shale land, and none of it has been included in a naval oil-shale reserve. The area underlain by oil shale in Colorado and Wyoming and a small area near Watson, Utah, are shown on maps contained in United States Geological Survey *Bulletin* 641-F, a copy of which may be obtained free on application to the Director, United States Geological Survey, Washington, D. C. The oil-shale area in Utah will be shown on maps to be included in a report on the last season's field work in that State."

In addition to the work mentioned above, Mr. George H. Ashley has examined many of the shale deposits in the Eastern States, as a result of which U. S. Geological Survey *Bulletin* 641-L, entitled "Oil Resources of Black Shales of the United States," has been published.

The Bureau of Mines has made examinations of the industrial value of many of these shales, including investigations of methods for their utilization.

The first effort on a large scale to utilize the deposits of oil shales in the Western States has been made by Mr. Robert M. Catlin, of Franklin Furnace, N. J., who has erected a new type of retort for the continuous treatment of these shales, which, at this date, is practically ready for operation on the shales just south of Elko, Nev.

California (By P. M. Paine).—The outstanding feature of the crude-oil situation in California during 1916 was the decline in the stocks on hand of 13,110,861 bbl. the shipments having exceeded the production by a daily average of 35,822 bbl. This was notwithstanding the fact that the daily production exceeded that of 1915 by 5493 bbl. The reduction in stocks of from 57 million barrels to 44 million barrels, with several increases in price offered the producers for crude, led to the rehabilitation of older and closed-in wells, and to the drilling of many new wells, both in the proved territory and in new localities of promise. While the latter have developed some minor extensions of the older fields the search for new fields has not been particularly encouraging, except in Los Angeles, Orange and Ventura Counties, and in these districts the new territory opened up has not been extensive. Wells completed during 1916 numbered 567, while abandonments were 80, a net gain of 487.

GROSS PRODUCTION AND SHIPMENTS OF CALIFORNIA[1] CRUDE OIL FOR THE YEAR 1916

(In barrels)

Prepared by the independent oil producers agency.

	Gross Production.	Daily Average.	Gross Shipments.	Daily Average.	Gross Stocks.	Decrease.	Daily Average.
Jan. 1, 1916					55,977,180		
January	6,936,785	223,767	6,963,161	224,618	55,950,804	26,376	851
February	6,522,548	224,915	7,193,499	248,051	55,279,853	670,951	23,136
March	7,525,081	242,744	8,368,869	269,963	54,436,065	843,788	27,219
April	7,372,480	245,749	8,785,715	292,857	53,022,830	1,413,235	47,108
May	7,724,184	249,167	8,829,250	284,814	51,917,764	1,105,066	35,647
June	7,643,136	254,771	8,512,641	283,755	51,048,259	869,505	28,984
July	8,073,307	260,429	8,341,119	269,068	50,780,447	267,812	8,639
August	8,079,023	260,614	9,548,075	308,002	49,311,395	1,469,052	47,388
September	8,020,699	267,356	9,445,632	314,854	47,886,462	1,424,933	47,498
October	8,260,357	266,463	9,190,114	296,455	46,956,705	929,757	29,992
November	7,881,447	262,715	9,468,181	315,606	45,369,971	1,586,734	52,891
December	7,936,972	256,031	9,666,649	311,827	43,640,294	1,729,677	55,796
1916	91,976,019	251,989	104,312,905	285,789	Decrease...	12,336,886	33,800
1915	89,725,776	245,824	92,007,715	252,076	Decrease...	2,281,939	6,252
Difference	2,250,243	6,165	12,305,190	33,713			

NOTE.—An average of approximately 18,000 bbl. daily production was shut in during the years 1915 and 1914.

FIELD OPERATIONS AND GROSS PRODUCTION CALIFORNIA CRUDE OIL, 1916

1916.	New Rigs.	Wells Drilling.	Wells Completed.	Wells Abandoned.	Wells Producing.	Gross Production. Districts.	Production (Barrels).
January	15	167	49	23	6,142		
February	37	176	41	11	6,040	Kern River	8,539,973
March	62	195	35	4	6,282	McKittrick	3,347,166
April	77	220	53	21	6,368	Midway Sunset	39,172,871
May	68	250	49	29	6,432	Lost Hills-Belridge	4,873,501
June	55	235	57	33	6,522	Coalinga	14,393,437
July	45	247	60	6	6,625	Lompoc-Santa Maria	4,370,055
August	62	248	51	8	6,696	Ventura-Newhall	1,086,285
September	59	259	64	19	6,762	Los Angeles-Salt Lake	1,729,761
October	61	286	42	25	6,845	Whittier-Fullerton	14,409,470
November	62	284	63	14	6,882	Summerland	53,500
December	66	286	57	20	6,908		
Average 1916	56	238	52				
Average 1915	14	153	28			Total	91,976,019

[1] *Mining and Oil Bull.*, Feb., 1917.

TOTAL PRODUCTION OF CALIFORNIA BY FIELDS IN BARRELS TO DATE[1]

Year.	Kern River.	Mc-Kittrick.	Midway.	Sunset.	Coalinga.	Santa Maria-Lompoc.	Summer-land.	Newhall and Ventura Co.	Los Angeles and Salt Lake.	Whittier-Fullerton.	Lost Hills-Belridge.	Miscel-laneous.	Total.
Prior....	....	....	....	....	....	....	....	3,283,262	....	....	....	....	3,283,262
1890	....	....	....	....	*	....	*	307,860	....	....	....	....	307,360
91	....	....	....	*	....	....	....	323,600	....	....	....	....	323,600
92	....	*	....	....	....	....	....	385,049	....	....	....	....	385,049
93	....	....	....	....	....	....	....	470,179	....	....	....	....	470,179
94	....	....	....	....	....	....	1,500	524,469	257,109	....	....	....	783,078
95	....	....	....	....	....	....	16,904	476,490	751,945	....	....	....	1,245,339
96	....	....	....	....	14,119	....	39,792	298,866	905,003	....	....	....	1,257,780
97	....	....	....	....	70,140	....	130,136	368,282	1,327,011	12,000	....	4,000	1,911,569
98	....	10,000	....	....	154,000	....	132,217	427,000	1,462,871	60,000	....	3,000	2,249,088
99	*	15,000	....	....	439,372	....	208,370	496,200	1,409,356	108,077	....	1,500	2,677,875
1900	826,775	80,000	*	12,500	547,960	....	183,486	443,000	1,722,887	254,397	....	248,945	4,319,950
01	3,278,840	430,450	4,235	188,600	525,433	*	203,616	472,057	2,304,432	302,652	....	....	7,710,315
02	8,988,046	619,296	3,048	167,558	571,233	86,888	143,552	475,000	2,198,496	1,103,793	....	....	14,356,910
03	16,342,099	1,353,206	27,305	352,565	2,138,058	204,890	131,125	682,185	793,765	2,305,613	....	3,670	24,334,481
04	17,226,240	1,856,225	910	390,425	5,097,853	700,450	120,506	650,779	1,241,304	2,224,550	....	39,392	29,548,634
05	15,253,845	1,373,030	18,530	419,212	8,882,125	3,402,800	96,871	476,898	2,226,768	2,118,312	....	29,650	34,298,041
06	12,825,166	680,756	11,800	307,550	8,401,105	4,799,411	72,810	404,379	2,675,650	2,434,512	....	10,090	32,623,229
07	12,346,014	2,415,840	149,944	704,805	8,996,268	8,249,236	69,060	435,584	3,372,465	3,294,206	....	69,090	40,102,512
08	13,803,579	3,076,300	434,578	1,463,510	10,725,795	8,699,350	67,862	498,015	5,138,959	4,273,314	....	125,475	48,306,737
09	14,508,242	5,807,360	2,234,455	1,999,701	15,406,619	8,017,455	66,338	516,628	4,350,898	5,157,252	....	126,775	58,191,723
1910	14,776,435	5,471,613	11,174,207	9,218,901	18,646,570	7,607,830	74,725	652,575	3,729,618	6,281,221	4,900	58,970	77,697,568
11	14,078,890	5,477,532	21,584,602	6,559,069	18,311,251	7,465,074	71,255	661,785	3,223,661	7,081,165	168,410	61,350	83,744,044
12	12,446,445	5,094,465	25,948,980	5,590,824	19,546,122	6,801,966	65,715	859,885	3,073,427	7,919,779	2,680,961	45,870	90,074,439
13	9,980,940	4,496,842	33,040,129	5,984,651	18,604,626	5,817,711	62,406	1,022,052	2,898,846	10,657,053	5,274,553	27,375	97,867,184
14	7,030,545	3,820,857	37,479,228	12,546,615	15,925,887	4,303,080	55,743	968,421	2,504,475	14,130,548	4,830,921	27,375	103,623,695
15	8,034,794	3,552,801	33,311,846	6,006,607	13,548,159	4,536,840	53,000	1,036,305	2,110,133	13,030,549	4,318,550	27,375	89,566,779
16	8,402,525	3,230,644	32,156,818	6,768,658	14,381,493	4,422,410	56,775	1,122,033	1,721,453	14,679,672	4,852,431	27,450	91,822,362
Total...	190,149,600	48,862,217	197,580,255	57,681,754	180,934,188	75,115,391	2,123,764	18,738,338	51,400,532	97,428,665	22,130,726	937,352	943,082,782

* Indicates first well.

[1] From *Gulf Coast Oil News*, Mar. 24, 1917.

The opinion of oil authorities in the State is emphatic that further oil developments must be sought vertically rather than by lateral extension. The Government restrictions on drilling and the contested ownership of certain important tracts on the West Side field, due to the old withdrawal complications, gave great interest to the proposed leasing bill, which reached a position where it only remained to be called up in the Senate for final passage. This failed by the complications incident to the early adjournment of Congress. The bill will undoubtedly be passed at the next session, with great relief to the California industry.

FLUCTUATIONS IN PRICES, PER BARREL, OF CALIFORNIA OIL IN 1916

	Jan. 1.	Feb. 16.	Apr. 1.	July 7.	Sept. 20.	Nov. 21.	Grade.	1915.	
								High.	Low.
San Joaquin Valley:									
14–17.9 degrees	$0.43	$0.53	$0.58	$0.63	$0.68	$0.73	14–20.9°	$0.40	$0.32½
(*a*) 18–18.9 degrees	0.44	0.54	0.59	0.64	0.69	0.74	21–26.9°	0.45	0.40
(*b*) 25–29.9 degrees	.....	.....	.....	0.72	0.77	0.82	27–30.9°	0.50	0.45
(*c*) 37–37.9 degrees	.....	.....	.....	.....	1.02	1.07	31° and over	0.55	0.50
Ventura County:									
25–25.9 degrees	0.67	.....	(*d*)	0.72	0.77	0.82	21–26:9°	0.50	0.50
37–37.9 degrees	.....	.....	.....	.....	1.02	1.07	27–30.9°	0.60	0.60
Whittier-Fullerton-Santa Maria:	.....	.....	.....	.....	.....	.....	31° and over	0.70	0.70
16–17.9 degrees	0.48	0.53	0.58	0.63	0.68	0.73	18–20.9°	0.45	0.40
18–18.9 degrees	0.49	0.54	0.59	0.64	0.69	0.74	21–26.9°	0.47½	0.42½
25–25.9 degrees	.....	.....	0.67	0.72	0.77	0.82	27–30.9°	0.57½	0.52½
37–37.9 degrees	.....	.....	.....	.....	1.02	1.07	31° and over	0.62½	0.60

(*a*) 1 ct. more for each degree over 18 to 25.
(*b*) 2 cts. more for each degree over 25 to 37.
(*c*) 3 cts. more for each degree over 37.
(*d*) The premium on Ventura County oil was increased Apr. 1 from 1 to 2 cts. for each degree over 25 and to 37 degrees.

Mid-Continent Region.—It was stated in the previous report that among the more interesting features of oil production in the Mid-Continent region in 1915, were certain improvements in oil-well drilling, introduced chiefly by the Bureau of Mines. In 1916 an equally important technologic advance was made in the search for oil. The recognition by oil producers of the value of geological exploration in a search for oil fields increased enormously, with a result that hundreds of oil geologists were retained, and the results of their work have been emphatically endorsed by the oil fraternity, so that future development of Oklahoma, Kansas, Texas and Louisiana will undoubtedly be based entirely upon careful geologic work.

(By Mr. Dorsey Hager).—From a geological viewpoint, no feature has been more striking than the attention given to geology in the Mid-Continent oil fields in the past 4 years.

In 1916, between 450 and 500 men were employed in geological work in the Mid-Continent oil fields, as against four or five in 1913. There are, I should judge, 250 geologists in these fields and the other men are assistants, instrument men and rod men, nearly all of whom have had geologic and engineering training but have not had enough experience to be classed as geologists though they are generally known as such.

The growth of geology is due to the fact that in the past 4 years, 1913, 1914, 1915 and 1916, 32 out 45 pools, or 71 per cent. of the pools discovered, have been the result of geological work.

The success in average "wildcatting" without geologic guidance, is one test in one hundred and fifty. Geologic work has reduced this to one in three.

Of notable strikes in Oklahoma in 1916, the Fox pool north of Healdton; the Billings, and the Garber oil pools in the Red Bed area of Central Oklahoma are due to the work of geologists. In 1915, the Eldorado and the Augusta, Kansas, oil pools were the most notable geologic strikes.

All these oil pools showed an anticlinal structure. The old idea that folding was absent in the Mid-Continent has been completely upset, as over 93 per cent. of the pools in this area are on definite folds.

The rise in price of the oils in the first part of the year was responsible for a great drilling campaign, which discovered a valuable pay sand below the Bartlesville in the Cushing district, and developed many wells of gusher dimensions in the Shamrock or southern extension of the Cushing district in Creek County. The Healdton district in Carter County was occasionally drilled, with a great increase in production. The Blackwell field in Kay County was sufficiently successful to maintain interest in its development, and a valuable addition to the oil supply was developed in the Osage Reservation, near Hominy. Wagoner, Noble and Garfield Counties added to the interesting results, and altogether the supplies largely outside of the Cushing district were sufficient to check the drainage on oil stocks in the Mid-Continent region and to again decrease the price of the product until late in the year, when the stocks were again drawn upon, with the usual rise in price, details of which are given elsewhere.

Colorado.—Only desultory drilling was attempted in this State because of the greater fascination in the oil regions to the north in Wyoming, and production consequently declined. Production figures follow on p. 540.

Illinois.—The following statement is given by John D. Northrop in the United States Geological Survey *Press Bulletin*, June, 1917.

"The stimulus to field activity supplied by the more favorable market for petroleum in 1916 resulted in the completion of 1461 new wells during the year as compared with 757 in 1915. Of these 1107, or 76 per cent., produced oil, 36 produced gas only, and 318 were barren of either.

"Field activity in Illinois in 1916 included 18 counties in its scope, Crawford leading in the number of new wells completed, but Lawrence

PETROLEUM MARKETED IN COLORADO IN 1915 AND 1916
(By districts in barrels)

Month.	1915. (a)			1916. (b)		
	Boulder.	Florence.	Total.	Boulder.	Florence.	Total.
January	901	17,381	18,282	825	15,829	16,680
February	545	15,213	15,758	500	13,847	14,392
March	579	15,738	16,317	532	14,325	14,890
April	638	17,386	18,024	585	15,824	16,444
May	478	14,549	15,029	440	13,242	13,717
June	442	13,580	14,022	407	12,333	12,802
July	596	16,726	17,322	547	15,224	12,805
August	501	14,098	14,599	461	12,832	15,805
September	210	15,697	15,907	196	14,287	13,127
October	571	16,125	16,696	615	14,677	14,517
November	454	20,603	21,056	418	18,752	19,203
December	461	24,974	25,435	424	22,728	23,188
Total	6,376	202,069	208,475	5,950	184,050	190,000

(a) Geol. Survey figures.
(b) Estimated.

leading in the volume of new production obtained. The combined output for the first day of productive life of all oil wells completed in Illinois in 1916 was 24,789 bbl., an average of 22.4 bbl. for each well, which is less by 3.9 bbl., or 15 per cent., than the corresponding average in 1915.

"The larger proportion of the oil produced in Illinois in 1916 came as usual from the fields in the southeastern part of the State, in which operations were restricted in the main to proved territory. Efforts to develop an oil pool of consequence in the southwestern part of Allison Township, Lawrence County, were unsuccessful. Several oil wells with initial yields above the average of the wells previously drilled were completed during the year in the Allendale pool, Wabash County.

"In western Illinois wildcat activity west of the Colmar district, in McDonough County, resulted in the partial development of a small pool of oil on the Aleshire farm in secs. 13 and 24, St. Marys Township, Hancock County.

"In Henderson County, some distance north of the Colmar district, encouraging showings of oil were found late in 1916 in test wells drilled near Biggsville.

"In the central part of the State completion in January, as an oil well, of a wildcat test drilled in sec. 12, Breese Township, Clinton County, about 3 miles west of the Carlyle pool, resulted in the drilling of additional tests in the locality that failed to justify the hope that an important new source of oil production had been discovered.

"Unsuccessful wildcat tests were completed in 1916 in Pea Ridge Township, Brown County; in Otego Township, Fayette County; near Eldorado, Saline County; near Campbell Hill, Jackson County; and near Birmingham, Schuyler County."

PETROLEUM MARKETED IN ILLINOIS, 1912–1916, IN BARRELS (a)

Month.	1912.	1913.	1914.	1915.	1916. (b)
January	2,241,867	2,149,264	1,935,492	1,614,026	1,373,615
February	2,262,440	1,859,412	1,570,790	1,542,383	1,330,016
March	2,369,428	2,008,245	1,969,915	1,761,099	1,552,827
April	2,351,693	2,015,058	1,833,099	1,643,479	1,396,454
May	2,535,039	2,117,425	1,970,688	1,638,733	1,572,217
June	2,503,038	2,003,278	1,932,303	1,603,733	1,527,589
July	2,698,582	2,075,444	1,907,521	1,636,932	1,540,887
August	2,519,651	2,001,228	1,844,983	1,593,436	1,561,066
September	2,366,712	1,942,052	1,817,437	1,535,040	1,467,892
October	2,424,472	1,982,002	1,813,364	1,533,972	1,522,930
November	2,174,856	1,819,116	1,678,783	1,452,285	1,454,302
December	2,153,530	1,921,375	1,645,374	1,486,577	1,414,440
	28,601,308	23,893,899	21,919,749	19,041,695	17,714,235

(a) Geol. Surv. figures.
(b) Estimated.

FLUCTUATIONS IN PRICES, PER BARREL, OF ILLINOIS OIL IN 1916

Date.	Illinois.	Plymouth.
Jan. 1	$1.47	$1.33
3	1.57	.....
21	.....	1.38
27	1.62	1.43
Feb. 16	1.72	.....
Mar. 6	.....	1.48
13	.....	1.58
16	1.82	1.68
July 28	1.72	1.58
Aug. 1	1.62	1.48
4	1.52	1.38
14	1.47	1.18
Nov. 17	.....	1.08
18	1.52	.....
Dec. 13	1.57	1.18
19	1.62	1.28
28	.....	1.38
1915 High	$1.47	$1.33
Low	0.84	0.43

Indiana.—Without significant results prospecting was still continued in many parts of the State, with a 50-bbl. result in Washington Township, Gibson County, near Hazelton, with the possibility of the northern extension of the Princeton pool.

PETROLEUM MARKETED IN INDIANA, 1912–1916, IN BARRELS

Month.	1912. (a)	1913. (a)	1914. (a)	1915. (a)	1916. (b)
January	64,403	73,237	109,891	82,390	94,258
February	62,991	70,336	97,045	85,690	98,086
March	81,148	57,204	120,508	76,939	87,935
April	92,965	78,764	126,670	82,683	94,588
May	101,102	77,379	128,493	75,922	86,755
June	85,819	73,056	129,855	78,934	90,249
July	90,011	73,838	121,122	72,189	82,425
August	86,492	72,467	109,939	66,452	75,770
September	78,432	81,462	110,299	62,010	70,617
October	83,634	91,368	105,969	66,332	75,532
November	69,733	98,444	88,272	58,447	66,485
December	73,279	108,549	87,393	67,770	77,300
Total	970,009	956,095	1,335,456	875,758	1,000,000

(a) Geol. Surv. figures.
(b) Estimated.

FLUCTUATIONS IN PRICES, PER BARREL, OF INDIANA OIL IN 1916

Date.	Princeton.	Indiana.
Jan. 1	$1.47	$1.18
3	1.57	1.28
22	....	1.33
27	1.62	1.38
Feb. 7	....	1.43
16	1.72	....
Mar. 7	....	1.48
16	1.82	1.58
July 28	1.72	1.48
Aug. 1	1.62	1.43
4	1.52	1.33
14	1.47	1.28
Nov. 18	1.52	1.33
Dec. 13	1.57	1.38
19	1.62	1.43
1915 High	$1.47	$1.18
Low	0.84	0.78

FLUCTUATIONS IN PRICES, PER BARREL, OF OKLAHOMA-KANSAS OIL IN 1916

Date.	Oklahoma-Kansas.	Healdton.
Jan. 1	$1.20	$0.60
7	....	0.65
20	1.25	....
21	....	0.70
26	1.30	....
27	....	0.75
Mar. 4	1.40	....
11	1.45	....
13	....	0.80
14	1.55	....
July 24	1.45	....
25	....	0.70
29	1.35	....
31	0.31	0.60
Aug. 1	1.25	....
2	....	0.50
7	1.15	....
12	1.05	....
14	....	0.45
15	0.95	....
16	....	0.40
26	0.90	....
Nov. 29	1.00	....
Dec. 12	1.10	....
13	....	0.50
16	1.20	....
19	....	0.60
23	1.30	0.70
28	1.40	....
29	....	0.75
1915 High	$1.20	$0.60
Low	0.40	0.30

Kentucky.—A great change must be recorded in the condition of petroleum exploration in Kentucky. It centered on the development of the Irvine pool in Estill County. Second in interest was the development of the Scottsville district, in Allen County. The significance of the new development in Estill County is due to the fact that it resulted in very much more thorough geologic work than has previously been carried on in that State. By this work the Irvine anticline was thoroughly pointed out, especially by the work of R. W. Richards and associates. This anticline has been well defined as running in a general west to east, or slightly south to east, direction through the county, with opportunity for the development of oil wells far beyond those now producing. The real value of this discovery consists in the stimulus given to the thorough geological search for oil in Kentucky, especially in the southern part of the State. A more detailed statement of the results in Kentucky during 1916, by Mr. R. W. Richards, follows:

"The petroleum output of Kentucky was increased nearly 300 per cent. over that of 1915, and the production over 800 per cent.

"In Estill County, the Irvine Pool was extended until it has an area of 8 square miles, and an estimated daily production of 30,000 bbl. A new shallow pool was developed at Station Camp of about 5000 bbl. per day capacity.

"In Powell County, a rich pool was opened on the Ashley lease which is showing nearly 1000 bbl. per day.

"In Wolfe County, a new pool was opened, with its best well yielding after shooting 250 bbl. per day.

"In the above three counties the production is from the 'Corniferous sand' and consists of green oils which have been grouped to date under 'Somerset grade.' The geological conditions of occurrence have been outlined in *Bulletins* 471 and 531 of the U. S. Geological Survey.

"In Allen County the old Scottsville pool was extended until its daily production is about 2000 bbl. per day.

"Wells, which may be pointers to development in 1917, have been drilled in Bath, Barren, Floyd, Knox, Lincoln, Martin, Metcalf, Morgan and Whitley Counties.

"Limited pipe-line facilities are retarding the marketing of the oil, but steps have been taken to remedy these conditions.

PETROLEUM MARKETED IN KENTUCKY, 1912–1916, IN BARRELS (*a*)

Month.	1912.	1913.	1914.	1915.	1916. (*b*)
January	38,425	42,074	46,930	34,898	95,838
February	37,723	36,843	44,545	35,707	98,022
March	40,923	39,390	53,860	39,562	108,429
April	37,375	39,036	50,465	40,015	109,654
May	44,967	42,903	44,903	39,323	107,785
June	40,311	39,285	44,361	37,070	101,702
July	44,997	48,211	42,630	35,905	98,556
August	40,866	49,908	26,758	37,531	102,956
September	39,146	52,538	21,177	34,929	95,920
October	38,484	46,301	51,625	33,564	92,235
November	40,000	44,137	36,900	34,702	95,307
December	41,151	43,911	38,287	34,068	93,596
	484,368	524,568	502,441	437,274	1,200,000

(*a*) U. S. Geol. Surv. figures.
(*b*) Estimated.

"The remarkable advances of the year have destroyed the old time prejudice against the State, and unless misguided legislation is enacted, 1917 will see more extensive developments."

FLUCTUATIONS IN PRICES, PER BARREL, OF KENTUCKY OIL IN 1916

Date.	Somerset.	Ragland.
Jan 1	$1.63	$0.75
28	1.73	0.80
Feb. 21	1.78	0.82
Mar. 6	1.85	0.85
17	1.95	0.90
July 29	1.85	0.80
Aug. 3	1.75	0.75
10	1.70	....
15	1.65	....
Sept. 28	1.75	0.80
Oct. 10	1.85	0.85
20	1.95	0.90
31	1.90	....
Dec. 5	2.00	0.95
29	2.05	....
1915 High	$1.63	$0.75
Low	0.80	0.62

Louisiana.—In Louisiana active prospecting was continued in Caddo Parish, especially south of Caddo Lake, in the Mooringsport district and south of Shreveport, where oil wildcatting proved interesting. The De Soto district maintained its attractiveness by new developments in the neighborhood of Logansport. The Red River district yielded new oil territory southwest of Crichton, in Grand Bayou. An important gas well was obtained west of Lake Bistineau, near Ellen Grove, in Bossier Parish. One important gas well was struck southwest of Bastrop, in Morehouse Parish.

PETROLEUM MARKETED IN LOUISIANA IN 1915 AND 1916

Month.	1915.	1916. (*a*)
January	1,053,664	919,088
February	1,173,037	1,021,749
March	1,343,138	1,168,036
April	1,456,208	1,265,296
May	1,494,666	1,298,350
June	1,471,385	1,278,328
July	1,750,367	1,518,257
August	1,927,299	1,670,415
September	1,838,646	1,594,173
October	1,637,341	1,421,050
November	1,517,518	1,318,003
December	1,528,270	1,327,255
	18,191,539	15,800,000

(*a*) Estimated.

FLUCTUATIONS IN PRICES, PER BARREL, OF LOUISIANA OIL IN 1916

Date.	DeSoto.	Caddo, 38° and Above.	Caddo, 35°.	Caddo, 32°.	Caddo, Heavy.	Vinton.	Jennings.	Crichton.
Jan. 1	$1.10	$1.20	$1.10	$1.05	$0.80	$0.60	$0.45	$0.85
4						0.70	0.65	
11						0.80		
25	1.15	1.25	1.15	1.10	0.85			0.90
27								0.95
28	1.20	1.30	1.20	1.15	0.90			
Mar. 8	1.30	1.40	1.30	1.25				1.00
15	1.35	1.45	1.35	1.30				1.05
27	1.45	1.55	1.45	1.40				
June 15					0.80			0.90
22								0.80
July 14						0.70		
15								0.70
25		1.45	1.35	1.30	0.70			
26	1.35							
28						0.65		
29					0.65			0.65
31		1.35	1.25	1.20				
Aug. 1	1.25							
2	1.15	1.25	1.15	1.10				
8	1.05	1.15	1.05	1.00				
14	0.95	1.05	0.95	0.90				
16	0.85	0.95	0.85	0.90				
26	0.80	0.90	0.80	0.75				
29								0.60
Nov. 29	0.90	1.00	0.90	0.85				
Dec. 4								0.70
8						0.80	0.80	
14	1.00	1.10	1.00	0.95	0.75			0.80
19	1.10	1.20	1.10	1.05				0.90
20								
27	1.00	1.30	1.20	1.15				1.20
28					0.85			
29	1.30	1.40	1.30	1.25				1.10
30						1.00	1.00	
1915 High	$1.10	$1.20	$1.10	$1.05	$0.80	$0.60	$0.45	$0.85
Low	0.50	0.60	0.50	0.45	0.35	0.45	0.45	0.40

Montana.—The Elk Basin field of Wyoming was extended into southern Carbon County in 1916, with a little oil production, while many regions widely scattered over the State are known to have reached the exploitation stage.

Ohio.—The drilling campaign in 1916 covered the same general territory of central Ohio as in 1915, with the more successful results coming

PETROLEUM MARKETED IN OHIO 1912–1916, IN BARRELS (*a*)

Month	1912.	1913.	1914.	1915.	1916. (*b*)
January	587,871	744,203	785,588	653,673	618,127
February	602,747	640,138	592,847	635,550	601,101
March	760,741	603,816	808,089	709,525	670,638
April	807,680	805,276	787,654	699,202	660,934
May	834,201	754,623	765,522	645,119	610,095
June	770,561	732,174	759,813	672,723	636,043
July	804,975	752,144	793,570	658,404	622,583
August	818,621	729,945	515,146	633,241	598,930
September	732,376	744,466	611,574	630,554	596,405
October	791,758	789,356	821,557	642,166	607,319
November	710,490	702,108	648,586	603,897	571,346
December	746,986	783,219	646,406	641,272	606,479
	8,969,007	8,781,468	8,536,352	7,825,326	7,400,000

(*a*) Geol. Surv. figures.
(*b*) Estimated.

from the Union Furnace district. Persistent drilling southwest of Cleveland, in Cuyahoga County, yielded wells barely sufficiently to encourage the wildcatting. In northwestern Ohio good results were obtained in the drilling in Seneca County, near Tiffen, and activity was also considerable in Wood County. With considerable patience old territory was redrilled in Van Wirt County, with encouraging results.

FLUCTUATIONS IN PRICES, PER BARREL, OF OHIO OIL IN 1916

Date.	Lima.	Corning.	Wooster.
Jan. 1	$1.33	$1.75	$1.50
3	1.43	....	1.60
22	1.48	....	1.65
27	1.53	....	1.70
28	....	1.85	....
Feb. 7	1.58	....	1.75
21	....	1.90	....
Mar. 6	....	2.00	....
7	1.63	....	1.80
16	1.73	....	1.90
17	....	2.10	....
July 28	1.63	....	....
29	....	2.00	....
Aug. 1	1.58	....	1.80
3	....	1.90	....
4	1.48	....	1.70
10	....	1.85	....
14	1.43	....	1.65
15	....	1.80	....
Sept. 28	....	1.90	....
Oct. 10	....	2.00	....
20	....	2.10	....
Nov. 18	1.48	....	1.70
Dec. 5	....	2.20	....
13	1.53	....	1.75
19	1.58	....	1.80
29	....	2.25	....
1915 High	$1.33	$1.75	$1.50
Low	0.83	0.83	1.15

New York.—The oil operators in southern New York have continued to exercise the remarkable thrift which has rendered profitable the pumping of old wells yielding not more than 1 gal. of oil per day as an average in several individual oil pools. This easily constitutes the world's record for efficiency in oil-well operation. It constitutes the chief feature of interest in this region during 1916, and the economic conditions which make the industry profitable under these conditions is well worth the careful study of oil operators generally.

Pennsylvania.—In Pennsylvania the conditions are much the same as in New York State. The rise in price of Appalachian oil stimulated the cleaning out and continued working of old stripping, and much drilling was carried on within old proven territory. Incidentally new discoveries, such as those at Dorseyville, in Allegheny County, Spring Hill, in Greene County, etc., are of very slight interest.

PETROLEUM MARKETED IN PENNSYLVANIA AND NEW YORK, 1912–1916(a)
(In barrels.)

Month.	1912.	1913.	1914.	1915.	1916(b)
Pennsylvania					
January	562,665	669,134	677,284	629,588	642,540
February	575,180	577,763	532,826	615,005	627,865
March	686,178	637,250	726,605	672,343	686,150
April	699,856	703,829	782,378	697,036	711,337
May	728,127	700,585	701,685	638,490	651,620
June	657,545	661,542	724,172	683,410	697,438
July	678,789	688,055	731,080	682,583	696,595
August	675,848	653,090	646,412	655,242	668,707
September	634,114	651,046	688,761	654,036	667,477
October	686,184	693,996	704,024	645,333	658,599
November	610,314	609,033	614,126	623,955	636,794
December	643,148	671,979	640,982	641,684	654,878
	7,837,948	7,917,302	8,170,335	7,838,705	8,000,000
New York					
January	64,850	80,906	78,983	74,101	75,120
February	63,080	66,969	62,424	67,755	68,712
March	73,371	74,592	80,660	79,840	80,916
April	79,188	82,580	88,268	79,018	80,087
May	82,035	83,742	84,548	75,114	76,147
June	73,950	77,819	84,110	76,408	77,451
July	75,875	83,237	84,783	79,012	80,081
August	74,663	78,005	75,512	72,531	73,535
September	68,884	78,594	76,102	72,914	73,923
October	76,766	84,480	81,569	72,399	73,402
November	68,045	74,437	71,593	66,218	67,158
December	73,421	82,830	70,422	72,468	73,472
	874,128	948,191	938,974	887,778	900,000

(a) Geol. Surv. figures.
(b) Estimated.

FLUCTUATIONS IN PRICES, PER BARREL, OF PENNSYLVANIA OIL IN 1916

Date.	Pennsylvania.	Newcastle.	Mercer Black.	Cabell.
Jan. 1	$2.25	$1.75	$1.75	$1.78
28	2.35	1.85	1.85	1.88
Feb. 21	2.40	1.90	1.90	1.95
Mar. 6	2.50	2.00	2.00	2.02
17	2.60	2.10	2.10	2.12
July 29	2.50	2.00	2.00	2.02
Aug. 3	2.40	1.90	1.90	1.92
10	2.35	1.85	1.85	1.87
15	2.30	1.80	1.80	1.82
Sept. 28	2.40	1.90	1.90	1.92
Oct. 10	2.50	2.00	2.00	2.02
20	2.60	2.10	2.10	2.12
31	....	....	....	2.07
Dec. 5	2.75	....	2.20	2.17
29	2.85	....	2.30	2.22
1915 High	$2.25	$1.75	$1.75	$1.78
Low	1.35	0.97	0.97	0.97

Tennessee.—Thorough geological exploration similar to that which recently proved fruitful in Estil County, Kentucky, has been applied to the old oil regions of Tennessee, with a resulting interesting development at Glenmary, which is described by L. C. Glenn,[1] which report includes

[1] *Res. of Tenn.*, Jan., 1917.

the information that during the past summer an oil well was drilled on the Capitol Creek flats about ¾ mile northwest of Glenmary, Scott County, Tenn. The geological structure in this region presents a long monocline rising slightly to the west or west-northwest. The rate of rise at Glenmary is between 30 and 40 ft. per mile. No evidence was found of any fold or flattening or other interruption of this general rise of the rocks northwestward. No anticlinal structure was discovered. The oil seems to occupy a certain level in the rocks and has possibly been driven to its present position by salt water. Drilling in a general northerly or southerly direction from the present well, and so along the strike of rocks, should reach the oil-bearing strata at the same elevation as the Pemberton well. It is too early to predict the size of the pool, but it has a favorable outlook. The well proves on continuous pumping to hold up steadily. Drilling began June 5, 1916, and was finished Aug. 31, yielding the following log:

RECORD OF PEMBERTON WELL NO. 1.

	Thickness, Feet.	From, Feet.	To, Feet.
Soil	3	0	3
Hard white sand	42	3	45
Black slate	105	45	150
Hard white sand	155	150	305
Slate	130	305	435
Coarse loam sandstone	105	435	540
Black slate	7	540	547
Hard white sandstone, base of Lee	183	547	730
Slate and lime shells, top of Pennington	45	730	775
Red shale	20	775	795
Black slate	27	795	822
Dark lime	73	822	895
Red shale	13	895	908
Dark lime	22	908	930
Black slate, base of Pennington	20	930	950
Limestone, top of St. Louis	98	950	1,048
White slate	3	1,048	1,051
Dark lime	93	1,051	1,144
Black slate	3	1,144	1,147
Gray sand	8	1,147	1,155
Hard white lime	77	1,155	1,232
Gray sand and small pebble, oil-bearing	8	1,232	1,240
Hard white lime	4	1,240	1,244

Salt water was struck at 505 ft. and a little show of gas at 1045 ft. On Aug. 30, there were 640 ft. of oil in the well and on Aug. 31, 700 ft. There was little or no gas with the oil.

The oil is dark green in color. An examination by a private laboratory is reported as follows:

DISTILLATION TABLE OF GLENMARY OIL

	Per Cent.	Gravity Baumé.
Crude oil	....	38.4
Fraction up to 302° F.	19	65.2
Fraction 302° to 380°	10	51.5
Fraction 380° to 550°	19	42.3
Residue at 550°	50	23.8
Loss	2	....

DISTILLATION OF THE GASOLINE FROM CRUDE GLENMARY OIL

Up To	Per Cent.
194°	30
212°	46
230°	58
248°	72
266°	78
284°	84
302°	88
320°	91
338°	93
356°	95
374°	96
420°, end point	98

Texas (By E. G. Woodruff).—The two outstanding features in oil development in Texas and Louisiana during 1916 were the deep-sand developments at Electra and Goose Creek and the decline of the deep sand at Humble.

At Electra new wells began coming in in January and continued throughout the year. Several of these were between 1000 and 2000 bbl. daily initial production. In this same region Burkburnett gave several small wells distributed over a considerable territory which promise extensions of the already developed fields.

The sensational feature of the Gulf Coast country was the development of good pay at Goose Creek, Harris County, Texas. In this territory the first well came in during the latter part of August with an initial production of 8000 bbl. This lead to renewed activity in this field, with many wells drilling at the close of the year. During the latter weeks of the year several wells between 1500 and 2500 bbl. were brought in. Humble showed a steady decline throughout the year, though a large number of good wells ranging from 1000 to 5000 bbl. were brought in. Two unusually large wells, one at 8000 bbl., and another at 9000 bbl., came in during the year. During the latter part of the year a 2500-bbl. well was considered good. Air was applied to the wells, but there was a steady and marked decline in the production. Sour Lake failed to yield any sensational features, but during the latter half of the year gave several wells ranging from 1500 to 2000 bbl., initial production. Saratoga and Batson yielded nothing of special interest. Vinton, Louisiana, produced several large wells; one in January started at 12,500 bbl., and another at 4000; in February there was one at 1200 and one at 1000 bbl. In September there was a 3000-bbl. well, with other smaller wells during the latter part of the year. Edgerly showed the usual activity, which yielded a 2500-bbl. well in March, an 1800-bbl. well in June and a 4000-bbl. well in September, with several smaller wells.

In Northwestern Louisiana remarkable production was the development of unusually large gas wells in Bossier Parish. These wells range up to an initial production of 30,000,000 cu. ft. of gas. The available supply is so far in excess of the demand that most of these large wells are shut in. It is estimated that 500,000,000 cu. ft. were available from Bossier Parish at the close of the year. A large well within 2½ miles of Shreveport gauged 38,000,000 cu. ft. of gas. The largest oil production in Northwest Louisiana came from Red River and De Soto Parishes. In the Creighton district a 4000-bbl. well came in in January, others ranging from 1000 to 2000 bbl. In the Caddo district a 1500-bbl. well came in in March and later several other good completions. In De Soto Parish, March yielded a 1200-bbl. well. During the year wildcat activity was unusually large. Test wells were scattered over a great territory and were especially numerous in the Gulf Coast country and the Panhandle region. Promising wells which failed to prove any new territory were brought in in Panola County in northeast Texas, near Santa Anna, Coleman County; near Breckenridge in Stephens County; Holiday in Archer County; Brenham in Washington County; near Mineral Wells in Palo Pinto County; near Corpus Christi in Nueces County; Columbia in Brazoria County; and Palestine in Anderson County, Texas.

Oil or gas in small quantities was found in all of these fields; other prospecting was under way at the close of the year. The Thrall pool showed a steady decline; drilling failed to develop anything larger than a 40-bbl. well. The Strawn pool gave the usual number of small producers.

PETROLEUM MARKETED IN TEXAS, 1914–1916 IN BARRELS (a)

Month.	1914.	1915.	1916. (b)
January	1,503,652	1,590,719	1,659,398
February	1,392,109	1,727,168	1,800,265
March	1,726,475	1,818,055	1,895,827
April	1,860,873	1,820,619	1,898,494
May	1,878,982	1,738,578	1,813,171
June	1,865,029	1,774,338	1,850,362
July	1,720,868	1,958,288	2,041,670
August	1,695,372	1,834,068	1,912,481
September	1,621,551	2,215,396	2,309,062
October	1,720,646	2,729,713	2,843,952
November	1,566,217	3,137,359	3,267,903
December	1,516,410	2,598,400	2,707,415
	20,068,184	24,942,701	26,000,000

(a) Geol. Surv. figures.
(b) Estimated.

FLUCTUATIONS IN PRICES, PER BARREL, OF COASTAL TEXAS OIL IN 1916
Gulf Coast Quotations by Sun Pipe Line

	January.			July.		December.			1915.	
	1.	5.	10.	18.	27.	2.	14.	30.	High.	Low.
Batson	$0.60	$0.70	$0.80	$0.70	$0.65	$0.75	$0.80	$1.00	$0.50	$0.40
Dayton	0.60	0.70	0.80	0.70	0.65	0.75	0.80	1.00	0.50	0.40
Humble	0.60	0.70	0.80	0.70	0.65	0.75	0.80	1.00	0.50	0.40
Saratoga	0.60	0.70	0.80	0.70	0.65	0.75	0.80	1.00	0.50	0.40
Sour Lake	0.60	0.70	0.80	0.70	0.65	0.75	0.80	1.00	0.50	0.40
Spindletop	0.60	0.70	0.80	0.70	0.65	0.75	0.80	1.00	0.50	0.40

Moran (in Shackelford County) showed discouraging results. There was nothing new in the Corsicana oil field or the Mexia gas field.

Gulf Coast Quotations by Gulf Refining Co.

	January.			July.		December.		1915.	
	1.	4.	8.	17.	27.	13.	30.	High.	Low.
Batson	$0.50	$0.70	$0.80	$0.70	$0.65	$0.80	$0.90	$0.50	$0.40
Edgerly	0.45	0.60	0.70	0.65	0.60	0.80	0.90	0.45	0.40
Humble	0.60	0.70	0.80	0.70	0.65	0.80	0.90	0.60	0.40
Saratoga	0.50	0.70	0.80	0.70	0.65	0.80	0.90	0.50	0.40
Sour Lake	0.60	0.70	0.80	0.70	0.65	0.80	0.90	0.60	0.40
Spindletop	0.55	0.75	0.85	0.75	0.70	0.80	0.90	0.55	0.45

Gulf Coast Quotations by the Texas Co.

	January.			July.		December.			1915.	
	1.	4.	11.	14.	28.	8.	20.	30.	High.	Low.
Humble	$0.60	$0.70	$0.80	$0.70	$0.65	......	$0.75	$1.00	$0.60	$0.40
Markham	0.50	0.70	......	......	0.65	......	0.75	......	0.50	0.45
Sour Lake	0.60	0.70	0.80	0.70	0.65	0.80	......	1.00	0.60	0.40

FLUCTUATIONS IN PRICES, PER BARREL, OF NORTH TEXAS OIL IN 1916

Date.	Corsicana, Light, Electra, Henrietta.	Corsicana, Heavy.	Thrall, Strawn, Moran.
Jan. 1	$1.20	$0.60	$1.05
7	......	0.65	......
21	1.25	0.70	......
27	1.30	0.75	1.30
Mar. 6	1.40	......	1.40
13	1.45	0.80	1.45
15	1.55	......	1.55
July 25	1.45	0.70	1.45
31	1.35	0.60	1.35
Aug. 2	1.25	0.50	1.25
8	1.15	......	1.15
14	1.05	0.45	1.05
16	0.95	0.40	0.95
26	0.90	......	0.90
Nov. 29	1.00	......	1.00
Dec. 13	1.10	0.50	1.10
19	1.20	0.60	1.20
23	1.30	0.70	1.30
29	1.40	0.75	1.40
1915 High	$1.20	$0.60	$1.05
Low	0.45	0.40	0.60

West Virginia.—In West Virginia wildcatting and developments within the limits of known oil pools was carried on with great activity in 1916, and except for the "thirty-foot" sand development near Mannington, Marion County, the results were merely incidental in developments from old pools. The Berea sand pool in Kanawha County was xtended to the northwest in the Cabin Creek district.

PETROLEUM MARKETED IN WEST VIRGINIA, 1912–1916 (*a*)
(In Barrels)

Month.	1912.	1913.	1914.	1915.	1916. (*b*)
January	694,619	978,401	855,886	777,702	702,717
February	801,699	936,733	770,300	754,034	693,055
March	983,502	970,900	919,377	848,926	780,069
April	1,018,955	1,026,129	900,998	801,046	736,123
May	1,153,945	1,003,425	864,519	767,685	705,532
June	1,172,331	995,098	872,074	789,545	722,571
July	1,174,367	1,009,383	897,065	780,749	717,512
August	1,190,552	939,479	272,098	761,111	699,503
September	981,052	928,610	675,518	752,751	691,837
October	1,013,980	956,772	985,724	716,638	658,055
November	918,313	893,274	799,728	720,267	662,049
December	1,025,647	983,095	866,746	794,344	729,977
	12,128,962	11,567,299	9,680,033	9,264,798	8,500,000

(*a*) Geol. Surv. figure.
(*b*) Estimated.

Wyoming.—The refinery completed by eastern capitalists at Greybull, in Big Horn County, Wyoming, changed hands and is operated now by the Greybull Refining Co. associated with the Midwest Refining Co. Productive activity was also stimulated by the completion of the Illinois Pipe Line Co.'s line from the Elk Basin field to Frannie.

PETROLEUM MARKETED IN WYOMING IN 1915 AND 1916 (*a*)
(In Barrels)

Month.	1915.	1916. (*b*)
January	338,069	501,735
February	254,930	378,689
March	354,381	525,877
April	196,834	292,708
May	248,088	368,564
June	395,364	586,533
July	394,182	584,683
August	437,165	648,398
September	372,956	553,368
October	452,994	671,825
November	388,540	576,433
December	412,022	611,187
Total	4,245,525	6,300,000

(*a*) U. S. Geol. Surv. figures.
(*b*) Estimated.

The following statement concerning petroleum results in Wyoming during 1916 has been contributed by Mr. F. G. Clapp:

"The year 1916 in the oil fields of Wyoming was one of growing excitement. Among the fields in which drilling was done are the Salt Creek, Powder River, Big Muddy, Brenning Basin, Lost Soldier, Pilot Butte, Grass Creek, Basin, Torchlight, Lovell, Little Buffalo, Moorcroft, and others. The largest producing field is still Salt Creek, but there are other fields in which fully as much excitement now exists. One of these is the Big Muddy field, just east of Casper, in which a number of good producers have been obtained in the Shannon sand and one in the Wall Creek sand.

While as yet not fully tested, the Big Muddy field promises to be one of the best in Wyoming. During the last of the year there were about 30 holes completed or drilling in that field. In the Salt Creek field the chief item of interest was the tapping of the Second Wall Creek sand for the first time, and the consequent enhancement of the value of that field. The Second Wall Creek is now recognized as one of the promising sands of Wyoming.

"During the year a bill was signed by the President allowing the leasing of the central portion of the Wind River Indian Reservation, causing a rush of locators and others to the Pilot Butte region 32 miles up the Wind River from Riverton on the Chicago and Northwestern Railroad. This field looks promising for the future. Another new development is at Lost Soldier, 85 miles southwest of Casper on Lost Soldier Creek, and prospects appear to be good. During the year oil was found at a shallow depth on Dry Pine Creek in Lincoln County, and gas was discovered southeast of Rock Springs.

"While the undeveloped fields of Wyoming show great promise geologically many difficulties are encountered in their development. First among these is danger of litigation regarding titles. An additional difficulty is that, while there are many productive sands in the State, not more than two or three productive ones are known in any particular locality, the value of others being still in doubt. There are also fields in which the productive sands are too deep to be tapped by present methods of drilling. The year 1917 is expected to show extensive development of pipe-lines and refineries, with the addition of several new producing fields. While we may expect a great boom for several years, Wyoming's length of life as an oil producer on a large scale will not equal that of Oklahoma."

Petroleum in Foreign Countries

North America

Canada.—The preliminary report of the Canadian Bureau of Mines on the production of petroleum in 1916 states that there has been comparatively little change in the production of petroleum during the past 3 years although since 1907 there has been a distinct falling-off. A bounty of 1½ cts. per gal. is paid on the marketed production of crude oil from Canadian oil fields through the Department of Trade and Commerce. From the bounty statistics it appears that the 1916 production in Ontario and New Brunswick was 198,123 bbl., on which bounties amounting to $104,014.13 were paid. The market value of the crude oil at $1.97 11/12 per bbl. amounted to $392,284. In Alberta there was a small production of crude oil, but no bounty was paid on this as the specific gravity was

WORLD'S MARKETED PRODUCTION OF CRUDE PETROLEUM, 1858–

Year.	Roumania.	U. S. A.	Italy.	Canada.	Russia.	Galicia.	Japan.[1]	Germany.
1858	3,500	....	......	....	....	....	....	....
1859	4,349	2,000	......	....	....	....	....	....
1860	8,542	500,000	36	....	....	....	....	....
1861	17,279	2,113,009	29	....	....	....	....	....
1862	23,198	3,056,690	29	11,755	....	....	....	....
1863	27,943	2,611,309	58	82,814	40,816	....	....	....
1864	33,013	2,116,109	72	90,000	64,586	....	....	....
1865	39,017	2,497,700	2,265	110,000	66,542	....	....	....
1866	42,534	3,597,700	992	175,000	83,052	....	....	....
1867	50,838	3,347,300	791	190,000	119,917	....	....	....
1868	55,369	3,646,117	367	200,000	88,327	....	....	....
1869	58,533	4,215,000	144	220,000	202,308	....	....	....
1870	83,765	5,260,745	86	250,000	204,618	....	....	....
1871	90,030	5,205,234	273	269,397	165,129	....	....	....
1972	91,251	6,293,194	331	308,100	184,391	....	....	....
1873	104,036	9,893,786	467	365,052	474,379	....	....	....
1874	103,177	10,926,945	604	168,807	583,751	149,837	....	....
1875	108,569	8,787,514	813	220,000	697,364	158,522	4,566	....
1876	111,314	9,132,669	2,891	312,000	1,302,528	164,157	7,708	....
1877	108,569	13,350,363	2,934	312,000	1,800,720	169,792	9,560	....
1878	109,300	15,396,868	4,329	312,000	2,400,960	175,420	17,884	....
1879	110,007	19,914,146	2,891	575,000	2,761,104	214,800	23,457	....
1880	114,321	26,286,123	2,035	350,000	3,001,200	229,120	25,497	9,310
1881	121,511	27,661,238	1,237	275,000	3,601,441	286,400	16,751	29,219
1882	136,610	30,349,897	1,316	275,000	4,537,815	330,076	15,549	58,025
1883	139,486	23,449,633	1,618	250,000	6,002,401	365,160	20,473	26,708
1884	210,667	24,218,438	2,855	250,000	10,804,577	408,120	27,923	46,161
1885	193,411	21,858,785	1,941	250,000	13,924,596	465,400	29,237	41,360
1886	168,606	28,064,841	1,575	584,061	18,006,407	305,884	37,916	73,864
1887	181,907	28,283,483	1,496	525,655	18,367,781	343,832	28,645	74,284
1888	218,576	27,612,025	1,251	695,203	23,048,787	466,537	37,436	84,782
1889	297,666	35,163,513	1,273	704,690	24,609,407	515,268	52,811	68,217
1890	383,227	45,823,572	2,998	795,030	28,691,218	659,012	51,420	108,296
1891	488,201	54,292,655	8,305	755,298	34,573,181	630,730	52,917	108,929
1892	593,175	50,514,657	18,321	779,753	35,774,504	646,220	68,901	101,404
1893	535,655	48,431,066	19,069	798,406	40,456,519	692,669	106,384	99,390
1894	507,255	49,344,516	20,552	829,104	36,375,428	940,146	171,744	122.564
1895	575,200	52,892,276	25,843	726,138	46,140,174	1,452,999	141,310	121,277
1896	543,348	60,960,361	18,149	726,822	47,220,633	2,443,080	197,082	145,061
1897	570,886	60,475,516	13,892	709,857	54,399,568	2,226,368	218,559	165,745
1898	776,238	55,364,233	14,489	758,391	61,609,357	2,376,108	265,389	183,427
1899	1,425,777	57,070,850	16,121	808,570	65,954,968	2,313,047	536,079	192,232
1900	1,628,535	63,620,529	12,102	913,498	75,779,417	2,346,505	866,814	358,297
1901	1,678,320	69,389,194	16,150	756,679	85,168,556	3,251,544	1,110,790	313,630
1902	2,059,935	88,766,916	18,933	530,624	80,540,044	4,142,159	1,193,038	353,674
1903	2,763,117	100,461,337	17,876	486,637	75,591,256	5,234,475	1,209,371	445,818
1904	3,599,026	117,080,960	25,476	552,575	78,536,655	5,947,383	1,419,473	637,431
1905	4,420,987	134,717,580	44,027	634,095	54,960,270	5,765,317	1,472,804	560,963
1906	6,378,184	126,493,936	53,577	569,753	58,897,311	5,467,967	1,710,768	578,610
1907	8,118,207	166,095,335	59,875	788,872	61,850,734	8,455,841	2,001,838	756,631
1908	8,252,157	178,527,355	50,966	527,987	62,186,447	12,612,295	2,070,145	1,009,278
1909	9,327,278	183,170,874	42,388	420,755	65,970,350	14,932,799	1,889,563	1,018,837
1910	9,723,806	209,557,248	50,830	315,895	70,336,574	12,673,688	1,930,661	1,032,522
1911	11,107,450	220,449,391	74,709	291,096	66,183,691	10,519,270	1,658,903	1,017,045
1912	12,976,232	222,935,044	53,778	243,336	68,019,208	8,535,174	1,671,405	1,031,050
1913	13,554,768	248,446,230	47,256	228,080	62,834,356	7,818,130	1,942,009	(*a*)995,764
1914	12,826,579	265,762,535	39,849	214,805	67,020,522	(*a*)5,033,350	2,738,378	(*a*)995,764
1915	13,229,913	281,104,104	(*a*)41,530	215,462	68,548,062	4,158,899	3,118,564	(*a*)995,764
1916(*a*	....	292,300,000	......	198,123	72,360,000	....	3,431,767	....
Total	131,210,350	3,908,861,244	847,138	23,907,195	1,741,243,033	126,840,251	33,601,489	13,961,333

[1] and Formosa. (*a*) Estimated.

1916 BY YEARS AND BY COUNTRIES, IN BARRELS OF 42 GAL.

India.	Dutch E. Ind.	Peru.	Mexico.	Trinidad.	Egypt.	All Other.	Total.	Year.
....	....	....	....	....	....	....	3,560	1858
....	....	....	....	....	....	....	6,349	1859
....	....	....	....	....	....	....	508,578	1860
....	....	....	....	....	....	....	2,130,917	1861
....	....	....	....	....	....	....	3,091,692	1862
....	....	....	....	....	....	....	2,762,940	1863
....	....	....	....	....	....	....	2,303,780	1864
....	....	....	....	....	....	....	3,715,524	1865
....	....	....	....	....	....	....	3,899,278	1866
....	....	....	....	....	....	....	3,708,846	1867
....	....	....	....	....	....	....	3,990,180	1868
....	....	....	....	....	....	....	4,695,985	1869
....	....	....	....	....	....	....	5,799,214	1870
....	....	....	....	....	....	....	5,730,063	1871
....	....	....	....	....	....	....	6,877,267	1872
....	....	....	....	....	....	....	10,837,720	1873
....	....	....	....	....	....	....	11,933,121	1874
....	....	....	....	....	....	....	9,977,348	1875
....	....	....	....	....	....	....	11,051,267	1876
....	....	....	....	....	....	....	15,753,938	1877
....	....	....	....	....	....	....	18,416,761	1878
....	....	....	....	....	....	....	23,601,405	1879
....	....	....	....	....	....	....	30,017,606	1880
....	....	....	....	....	....	....	31,992,797	1881
....	....	....	....	....	....	....	35,704,288	1882
....	....	....	....	....	....	....	30,255,479	1883
....	....	....	....	....	....	....	35,968,741	1884
....	....	....	....	....	....	....	36,764,730	1885
....	....	....	....	....	....	....	47,243,154	1886
....	....	....	....	....	....	....	47,807,083	1887
....	....	....	....	....	....	....	52,164,597	1888
94,250	....	....	....	....	....	....	61,507,095	1889
118,065	....	....	....	....	....	....	76,632,838	1890
190,131	....	....	....	....	....	....	91,100,347	1891
242,284	....	....	....	....	....	....	88,739,219	1892
298,969	600,000	....	....	....	....	....	92,038,127	1893
327,218	688,170	....	....	....	....	....	89,335,697	1894
371,536	1,215,757	....	....	....	....	....	103,562,510	1895
429,979	1,427,132	47,536	....	....	....	....	114,159,183	1896
545,704	2,551,649	70,831	....	....	....	....	121,948,575	1897
542,110	2,964,035	70,905	....	....	....	....	124,924,682	1898
940,971	1,795,961	89,166	....	....	....	....	131,143,742	1899
1,078,264	2,253,355	274,800	....	....	....	....	149,132,116	1900
1,430,716	4,013,710	274,800	....	....	....	(a)20,000	167,424,089	1901
1,617,363	2,430,465	286,725	....	....	....	(a)26,000	181,965,876	1902
2,510,259	5,770,056	278,092	....	....	....	(a)36,000	194,804,294	1903
3,385,468	6,508,485	345,834	220,653	....	....	(a)40,000	218,299,419	1904
4,137,098	7,849,896	447,880	320,379	....	....	(a)30,000	215,361,296	1905
4,015,803	8,180,657	536,294	1,097,264	....	....	(a)30,000	214,010,124	1906
4,344,162	9,982,597	756,226	1,717,690	....	....	(a)30,000	264,958,008	1907
5,047,038	10,283,357	1,011,180	3,481,610	169	....	(a)30,000	285,089,984	1908
6,676,517	11,041,852	1,316,118	2,488,742	57,143	....	(a)20,000	298,373,216	1909
6,137,990	11,030,620	1,330,105	3,332,807	142,857	....	(a)20,000	327,615,603	1910
6,451,203	12,172,949	1,368,274	14,051,643	285,307	9,150	(a)45,000	345,685,081	1911
7,116,672	10,845,624	1,751,143	16,558,215	436,805	205,905	(a)105,000	352,484,591	1912
7,930,149	11,966,857	2,133,261	25,902,439	503,616	94,635	(a)270,000	384,667,550	1913
6,190,476	(b)12,705,208	1,917,802	21,188,427	643,533	777,038	(c)620,000	399,264,168	1914
6,833,333	(b)12,386,808	2,487,251	32,910,508	(a)700,000	221,768	1,500,000	429,119,688	1915
....	....	....	....	....	....	....	....	1916
78,573,586	150,665,300	16,806,972	123,270,377	2,769,430	1,308,496	1,822,000	6,355,860,813	bbl.

(b) Includes British Borneo. (c) Includes 600,000 bbl. produced in Argentina.

below the standard set by the Petroleum Bounty Act and complete records have not as yet been received from the producers.

The total production of crude oil (exclusive of Alberta), in 1916 was therefore 198,123 bbl., valued at $392,284, as compared with a production in 1915 of 215,464 bbl., valued at $300,572, showing a decrease of about 8 per cent. in quantity, but on account of the higher price an increase of over 30 per cent. in total value.

The price of crude increased from $1.73 at the beginning of the year to $2.13 on Mar. 16, declining to $1.83 on Aug. 14 and increasing again to $1.98 at the end of the year, the average for the year being $1.979.

The Ontario production in 1916 was, according to the records of the Department of Trade and Commerce at Ottawa, 196,778 bbl.

The production in New Brunswick was 1345 bbl. as against 1020 bbl. in 1914.

Exports of petroleum entered as crude mineral oil in 1916 were 137,647 gal., valued at $11,439, and of refined oil 446,595 gal., valued at $48,137. There was also an export of naphtha and gasoline of 54,806 gal., valued at $14,195.

The total value of the imports of petroleum and petroleum products in 1916 was $14,701,521, as against a value of $8,047,781 in 1915.

The total imports of petroleum oils, crude and refined, in 1916 were 292,340,271 gal., valued at $14,600,674.

Mexico.—The year 1916 was one of comparative quiet in the Mexican oil fields. In consequence the industry prospered, and about 30,500,000 bbl. were exported, in addition to the consumption in oil refineries at Minititlan and Tampico. Everywhere the Mexican paid much closer attention to development of industries. The United States took the bulk of the shipments, while many cargoes went to Great Britain and a satisfactory trade was built up with South America. The new law of the Mexican Government regulating oil trade is looked upon as satisfactory respecting rights acquired under previous governments.

The only sensational feature in the producing fields was the Cerro Azul No. 4 gusher of the Huasteca Petroleum Co., near Tumbadero, which in one day gave a measured flow of 260,000 bbl.

PRODUCTION OF PETROLEUM IN MEXICO, 1908 TO 1915 INCLUSIVE

Year	Production in bbl.
1908	3,481,410
1909	2,488,742
1910	3,332,807
1911	14,051,643
1912	16,588,215
1913	25,902,439
1914	21,188,427
1915	32,910,508
1916	....

West Indies.—Trinidad.—The exports of asphalt decreased from 125,974 tons in 1914 to 113,017 tons in 1915. Petroleum shipments increased slightly to 300,000 bbl. from 260,000 bbl. in 1914. The prospects of the oil industry are bright, but are hampered by certain restrictions imposed on the export of oil and by the scarcity of tank steamers.

Dutch West Indies.—According to Consul George S. Messersmith, Curacao, Dutch West Indies, the name of the company erecting the petroleum refinery at Willemstad on the island of Curacao has been changed from the Bataafsche Petroleum Maatschappij to the Curacacosche Petroleum Maatschappij.

The progress of the work on the refinery has been impeded by the difficulty in securing promptly the delivery of the construction materials and machinery contracted for in the United States. The plant, which was to have been in operation by this time, will not be completed before October, 1917.

Central America

Costa Rica.—A contract has been entered into between the Costa Rican Government and a United States concessionaire for the exploitation of the Government-owned oil fields in Costa Rica, under the terms of which the concessionaire is required to organize, in Costa Rica or elsewhere, a limited company, to be called the "Costa Rica Oil Corporation," with a capital of not less than $2,000,000. The concessionaire had already begun operations before the official ratification of this contract, and drills had been imported into Costa Rica. These were erected close to the Amei River, in the vicinity of the Talamanca mountain range, and experiments were made there; the seepage showed signs of oil, but, it is said, not sufficient to justify continued operations, and the drills were closed down for the time being. It is anticipated, however, that further trials will be made in the neighborhood. A large exploration party has been sent to this field.

South America

Argentina.[1]—As the result of a conference held by the Administrative Commission in charge of the exploitation of the Petroleum Deposits of Comodoro Rivadavia, investigations are to be made with the object of showing the extent of the oil belt, the depths of the petroleum bearing strata, and the thickness of the same. The commission proposes to sink wells at different points within the reserved zone, which extends 11 kilometers inland from the wells now in exploitation, and report upon the same. Oil wells which were drilled 600 meters deep without encounter-

[1] Bull. of the Pan American Union, Feb., 1917.

ing oil, are to be sunk to a depth of 1200 meters, the limit of the boring capacity of the drills owned by the commission. In this way it is hoped to determine the commercial value of the Comodoro Rivadavia oil fields and the probable depths of the deposits.

Production is gradually increasing, and reached nearly 1,000,000 bbl. in 1916.

Bolivia.—According to Commercial Attache Wm. F. Montavon, Lima, early in 1916 investigations of the oil deposits in Bolivia were undertaken by Chilean interests, and plans were formed for exploitation of the petroleum field in the Department of Santa Cruz. Recently *El Diario* of La Paz stated that a Bolivian engineer had gone to the Provinces of Caupolican, Munecas, and Camacho in the Department of La Paz to make a technical investigation of certain oil-bearing lands which had been denounced there.

A commission of Chilean engineers who had been sent to investigate the petroleum deposits in eastern Bolivia, held by the Sociedad Petrolifera Santa Cruz, was wholly satisfied with its investigations, and considered the expectations of the company well founded. Oil was found at several points on the property of the company, and a geologist was left on the field to study the probable extent of the deposits.

Concerning the purpose of the company to transport the oil to consuming centers in Bolivia and Chile, the commission stated that it had found land suitable for the laying of pipe-lines, and pumps could be installed at intervals to force the oil from the lowlands about Santa Cruz to the highlands. The pipe-line would pass through Atocha and Uyuni, and once the oil was brought to the highlands the problem of transporting it to Antofagasta and Iquique would be simple. Branch pipelines would be built to carry oil to Bolivian mining centers. The Bolivian Government had extended every facility to the commission during its expedition of 51 days. The welcome of the Government was comprehended when it was remembered that one of the greatest obstacles to the development of Bolivia is the scarcity of fuel. Bolivian coal contains too much sulphur, and there is practically no timber available for fuel.

Peru.—Additional oil discoveries were made on the Huallaga River near Yurimaguas. The oil is of good quality. The production of oil from old fields increased to what will mean peak production unless new fields are developed.

Venezuela.—Six companies are engaged in development work on an extensive scale. The Caribbean Petroleum Co., Colon Development Co., Venezuelan Oil Concessions, Ltd., Venezuela-Falcon Oil Syndicate, Ltd., Bermudez Co., and Panji Concession. The first employed a force of 35 geologists and many native civil engineers for 2 years, exploring the whole country included in what is known as the Tregelles concession. The company selected over 1000 locations, 1235 acres each. For the first work it selected 2 sections, one on each side of Lake Maracaibo. Oil was found in all six wells drilled, and the value of the region proved.[1]

Ecuador.—Renewed activity was evident in the old oil fields near Santa Rosa in the province of El Oro. Judging by the conditions in the adjacent Lobitos field in Peru, the oil should be found commercially at about 1000 ft. Recently a law was passed exempting oil products and exports from fiscal and municipal taxes.

Europe

Great Britain.—The Scottish Mineral Oil Trade during 1916.[2]—As with so many of the staple industries of the country, the Scottish mineral oil trade, says the *Scotsman,* is now experiencing a demand for its products, and at prices never anticipated by those directing the companies. It is quite safe to say that during the year just completed the level of prices and the insistence of the demand have exceeded all experience or expectation, and this has been due to the fact that every one of the products is an essential for one purpose or another, and many of them are obtainable from no other source within the British Isles. The industry is thus playing a most important part in the national economy, and the only regret is that its resources are not larger. While it can be stated quite safely that the reserves of oil shale proved in the Lothians are inexhaustible for all the purposes of present generations, the output of the various products is always strictly limited by the capacity of the expensive and elaborate plant necessary for the manufacture of the products, and an additional and stricter limit is imposed at the present time by the shortage of labor.

During the first 12 months of the war the shale fields were a prolific ground for the recruiting sergeant, and quite one-quarter of the employees of the industry joined His Majesty's Forces. Their places have been filled to some extent by such other labor, generally of an inferior class, as could be obtained, but with all that has been done—including the employment of women—to maintain staffs, there is at the present time a shortage of labor amounting to many hundreds of hands, and representing many millions of gallons of crude oil per annum. Not many connected with the industry have foreseen the important position it would one day occupy, and it can probably be asserted with justification that those in charge of national affairs would be exceedingly pleased if Scotland could furnish a very much larger production of mineral oils than is at present

[1] Part of comprehensive report by Preston McGoodwin, American Minister, Caracas.
[2] *Petroleum Review*, Jan. 20, 1917.

possible. To this end the wholesale enlistment of the workers was stopped 18 months ago, but by that time the loss of men had already become serious, and the deficit has never been made up, with the result that much expensive plant has lain idle and unproductive at a time when its produce could ill be spared. In other industries it has been found possible to increase production in spite of the withdrawal of men, and this has been accomplished by the employment of women, by the adoption of labor-saving machinery and methods, and by speeding up. It might be supposed that the methods which have proved successful in other industries could be applied to the oil industry with similar results. In practice, however, it is found that the relentless competition to which the industry has so long been exposed had already caused the elimination of all avoidable labor and the adoption of every possible mechanical device to gain economy, and that the manual labor remaining gives little scope for the employment of any but able-bodied men. In some departments women are being employed with success, but in other instances the attempt to utilize their labor has failed, while, of course, they are inadmissible underground, where quite one-half of the labor in the industry is employed.

In spite of the difficulties resulting from the shortage of labor, with resulting restricted output, and the very high cost of all supplies, the companies were able to publish 6 months ago balance sheets which showed satisfactory progress towards recovery from the effects of the first year of war. The following table gives a summary of the gross earnings and the ordinary dividends paid for the last 4 years:

	1912–1913.		1913–1914.	
	Gross Earnings.	Dividend, Per Cent.	Gross Earnings.	Dividend, Per Cent.
Broxbourn	$322,559.58	10	$277,814.02	10
Oakbank	250,142.68	15	355,909.34	15
Pumpherston	659,602.54	35	681,921.75	25
Young's	430,702.80	5	390,345.61	4
	$1,663,007.60	....	$1,705,990.72	....

	1914–1915.		1915–1916.	
	Gross Earnings.	Dividend, Per Cent.	Gross Earnings.	Dividend, Per Cent.
Broxburn	$108,362.37	....	$227,570.23	7½
Oakbank	114,707.98	....	204,471.82	10
Pumpherston	360,428.70	10	657,099.36	25
Young's	117,556.93	....	233,531.11	....
	$701,055.98	....	$1,322,672.52	....

It will be noticed that the industry suffered a very severe setback for the first financial year completed under war conditions, but during the second period good progress has been made toward recovery, and it is to be expected that the results for the financial year now current will show for the industry as a whole practically a complete recovery.

Up till about a year ago, grave doubts were felt as to the position of the industry after the war, because it was anticipated that the cessation of hostilities would at once set free a great amount of the tonnage now employed on military work, and that this would open again the floodgates of foreign competition upon this country and bring in an acute form the difficulties which the industry has so often had to face in the past. It is now thought that the probabilities of this occurring are diminishing as time goes on; it seems probable that when the longed-for peace does arrive the tonnage to bring in the foreign oil in overwhelming quantities at low freights will be lacking, and that the industries of the country will be busy for some time—*e.g.*, on the work of replacing lost ships—which will itself result in demand at home. It even seems that there will be no great quantities of oil available for import.

Roumania.—Until the entering of Roumania into the war production was kept at a high level, and the total product increased correspondingly. The Bana-Moreni field led in interest. With the approach of hostile forces the Roumanians crippled the producing capacity to the greatest possible extent, with a bad outlook for the product of 1917.

PRODUCTION OF PETROLEUM IN ROUMANIA IN 1915, BY MONTHS, COMPARED WITH 1914

	1914, Metric Tons.	1915, Metric Tons.
January	139,974	168,811
February	132,473	138,286
March	161,833	162,408
April	147,975	150,716
May	147,486	149,738
June	148,775	136,605
July	148,905	134,457
August	137,220	128,808
September	129,517	128,854
October	161,247	135,003
November	147,884	126,169
December	180,037	113,290
Total	1,783,947	1,673,145

Russia.—The Petroleum Review of Mar. 31, 1917, gives the following comprehensive review of the petroleum industry in Russia during 1916:

The total production on all Russian areas during 1916, as against 1915, was as follows:

	1916, Poods.	1915, Poods.
Four main Baku areas	332,000,000	343,000,000
Hand-dug production	10,000,000	1,000,000
Surakhany	96,000,000	60,000,000
Binagadi	34,000,000	33,000,000
Isle Sviatoi	7,000,000	7,000,000
Total on Baku areas	479,000,000	444,000,000
Grosny area	102,000,000	88,000,000
Isle Tchleken	3,000,000	3,000,000
Maikop area	2,000,000	8,000,000
Emba district	15,000,000	17,000,000
Fergana district	2,000,000	2,000,000
General total	603,000,000	562,000,000

The above table shows an increase of 34,000,000 poods of petroleum in the whole of the Russian production as against that obtained during 1915.

The production on the Surakhany area has considerably exceeded all expectations, and during December last it amounted to 10,236,000 poods, being considerably higher than that obtained on the largest of the main areas, namely, the Saboontchi area, which has 1340 wells in exploitation. The total production on the Surakhany area during 1916 amounted to 95,707,000 poods. This is slightly less than that obtained on the Saboontchi area, and considerably larger than the production on any of the other areas. The Surakhany area has now acquired the privilege of being the main productive Baku area. The production on the Surakhany area during the last quarter of the year was as follows:

	Total Production, Poods.	Flowing Production, Poods.
October	8,695,000	2,500,000
November	8,332,000	1,754,000
December	10,236,000	4,659,000
Total	27,263,000	8,913,000

The flowing production on the Surakhany area during the last quarter of 1916 amounted to 32.7 per cent. of the total production.

The production of the various firms on the Surakhany area was as follows:

	Poods.
Nobel Bros	31,000,000
Russian Nafta Society	20,900,000
Baku Petroleum Co	12,500,000
Caspian and Black Sea Co	6,800,000
Benkendorf	6,200,000
Surakhany & Co	4,200,000
Mirzoeff & Co	3,000,000
Caspian Society	2,800,000
Baku Tiflis Co	2,400,000
Lianozoff & Co	1,400,000
Melikoff & Makhmuroff	1,600,000
Asadulaeff	1,200,000
Rilski Trustees	1,100,000
Other firms	1,000,000

The rich production which was obtained on this area has, of course, been followed by increased boring, namely, from 4480 ft. in July last to 6538 ft. in September, 7693 ft. in October, and 7938 ft. in November.

Nevertheless, owing to the present abnormal circumstances, the total boring shows a decrease of 17.9 per cent. as against 1915, which in its turn shows a decrease of 12 per cent. as against 1914. This great total decrease, however, has not yet resulted in any decrease in the production.

The production on the Binagadi area maintains on the level of about 2,000,000 poods a month, and during the year amounted to 34,495,000 poods, showing an increase of about 5.5 per cent. as against the preceding year.

The production on the Isle Sviatoi, notwithstanding the cessation of boring, has somewhat increased, and amounted to 600,000 poods a month.

The hand-dug production amounted to 2,392,000 poods during the last quarter, and to 9,600,000 poods for the year.

The Grosny production has exceeded all expectations, amounting during 1916 to 102,000,000 poods, 24,000,000 poods, or 16 per cent., more than the production obtained during 1915. This considerable increase is the more remarkable as there was a continuous decrease in boring, which in 1914 amounted to 275,814 ft., in 1915 to 178,143 ft., and in 1916 to 150,000 ft. This shows a decrease of 45.4 per cent. for the last 2 years. The total increase in the production on the Grosny area is due to that obtained on the new areas, where in 1916 it amounted to 33,000,000 poods as against 11,000,000 poods obtained during 1915, thus showing an increase of 200 per cent.; while, on the contrary, the old area shows a decrease of 8,000,000 poods, namely from 77,000,000 poods in 1915 to 69,000,000 poods in 1916.

The flowing production on the new Grosny area during the reported year is of no great importance, amounting only to 6 per cent. Boring on this area during the year shows considerable fluctuations, and the total has decreased as against the preceding year.

The production in the Emba district during 1916 amounted to 15,-200,000 poods, as against 16,500,000 poods obtained during 1915; and that obtained on the Maikop area and on the Isle Tchleken has also decreased.

The production of crude oil on the four main Baku areas during the last quarter of 1916 continued to decrease, as seen from the following table showing the production month by month, together with the daily average:

	Poods.	Poods.
October	26,485,000	Daily average 861,000
November	25,761,000	Daily average 859,000
December	26,233,000	Daily average 843,000
For the quarter	78,479,000	Daily average 853,000

The yearly production on the four main areas, amounting to 330,500

Note.—8.33 poods crude = 1 United States barrel of 42 gal.

poods and being 12,800,000 poods, or 3.8 per cent., less than during 1915, has, however, exceeded expectations. The following table shows the steady decrease in the production on the main Baku areas during the last 5 years:

	Total Production, Poods.	Flowing Production, Poods.
1912	419,100,000	13,200,000
1913	389,700,000	6,400,000
1914	338,600,000	10,700,000
1915	343,300,000	10,200,000
1916	330,500,000	27,100,000

The decrease in the production during 1916 as against 1915 amounted to 12,800,000, or 3¾ per cent. This decrease is very small, and would be of no importance but for the fact of the flowing production being so large, namely 27,100,000 poods.

Since 1909, when the flowing production amounted to 20,600,000 poods, the yearly flowing production has never reached such a high figure as during 1916. However, the baling production alone is of importance when comparing the obtained results. In 1916 it amounted to 303,400,000 poods, as against 333,100,000 poods baled during 1915, thus showing a decrease of 29,700,000 poods, or about 9 per cent.

As regards the production on separate areas, that on the Bibi-Eibat area amounted to 89,700,000 poods, as against 79,200,000 poods obtained in 1915, showing an increase of 10,500,000 poods, or 13.3 per cent.; while the production on the remaining three old areas decreased from 264,100,000 poods in 1915 to 240,800,000 in 1916, or by 23,300,000 poods, or 8.8 per cent.

The increase on the former area is practically entirely due to flowing oil obtained from two strata, one at 3120 ft. deep and the other at 2060 ft. deep. The Bibi-Eibat flowing production is, however, quite unreliable, as it considerably fluctuates from month to month, as shown in the following table:

BIBI-EIBAT FLOWING PRODUCTION DURING 1916

	Poods.
January	1,172,000
February	389,000
March	659,000
April	1,081,000
May	8,788,000
June	5,007,000
July	578,000
August	1,628,000
September	3,082,000
October	2,495,000
November	783,000
December	779,000

All operating firms but two show various decreases in their production, and the increase obtained by the two firms, namely, Messrs. Nobel Bros. and Zubaloff, is entirely due to the above-mentioned flowing on the Bibi-Eibat area. The total production of Messrs. Nobel Bros. on the four main areas amounted to 51,800,000 poods, including 16,600,000 poods of spouted oil obtained on the Bibi-Eibat area, as against 51,000,000 poods, including 10,400,000 poods of flowing oil, obtained in 1915, thus showing a small increase in the total production of 800,000 poods, but a considerable increase, namely, that of 6,200,000 poods, or 59.6 per cent., in the spouted production. On the other three areas the production of Messrs. Nobel Bros. has decreased by 5,400,000 poods, or 13.3 per cent.

The production of Zubaloff in 1916 amounted to 27,600,000 poods, as against 18,200,000 poods obtained during the preceding year—thus showing an increase of 9,400,000 poods, or 51.5 per cent. The production of all other principal firms has decreased during 1916, as shown in the following table:

	1915, Poods.	1916, Poods.
Baku Petroleum Co	23,000,000	19,400,000
Caspian Society	11,800,000	9,500,000
Caspian and Black Sea Co	22,600,000	19,600,000
Lianozoff	12,900,000	11,900,000
Moscow Caucasian Society	12,600,000	10,100,000
Oleum	3,800,000	2,800,000
Nagiev	4,000,000	2,200,000
Pitoeff & Co	8,000,000	6,900,000
Rilski Trustees	3,600,000	3,400,000
Ter-Akopoff	6,000,000	5,800,000

The production of the above ten firms has decreased by 16,700,000 poods. The production of all the remaining firms has also decreased. Generally 1916 may be characterized as a year of an extreme decrease in the baling production, only partly compensated for by unprecedented wealth in flowing oil. Such decrease is intimately connected with a corresponding decrease in boring which has been taking place for the last 3 years, as shown in the following table showing number of feet bored on the four main areas:

	Feet.
1913	456,183
1914	363,909
1915	334,759
1916	301,000

The above table shows that in comparison with 1913 the total boring during the last 3 years on the four main Baku areas has decreased by 368,781 ft., or 123,000 ft. a year.

Asia

Japan.—The production of petroleum increased in 1916 as the result of the importation of Russian and American oil well drilling machinery. The entire product amounted to 140,000,000 gallons. Akita district showed the greatest gain, the older districts declining. The exploitation of Formosa's oil fields made progress.

Oceanica

Australia.—A well was drilled to a depth of over 3000 ft. on the Hundred of Kongorong in the southeast of South Australia. Great thicknesses of probable shales and some brown coal were passed through and considerable natural gas obtained. After much discussion as to the significance of these shales they have been sent to an American authority for investigation. The finding of great thicknesses of sedimentaries is interesting.

Philippines.—According to Commercial Agent J. F. Boomer, Manila, the director of public works has recently made an inspection of the oil fields on what is known as the Bundo Peninsula, in Tayabas, with a view to determining the most feasible way to get drilling machinery and other apparatus to the fields. He reports that a way has been found, and that the bureau is prepared to undertake drilling operations in that region on brief notice. The inspection was made pursuant to a project now in the Philippine Congress to make careful surveys of the oil and mineral fields of the islands, with a view to conserving them to the Government.

Natural Gas

The year 1916 was one of general prosperity in the natural gas industry. The distributors of natural gas were called upon to meet the greatest demand in history, and really under the most adverse conditions, for without any new fields and with the gradual exhaustion of old ones, the demand forced the production of a larger quantity than has ever been previously produced. In 1915 the total product of natural gas amounted to 628,578,842,000 cu. ft., valued at $101,312,381. This increased to 660,006,900,000 cu. ft. (estimated) in 1916, valued at $106,378,858 (estimated).

Every known device was availed of by practically every company in the country to increase production and to prevent waste. So at the present time it may safely be said that the wasteful conditions of even 3 years ago have disappeared, and that the developments in conservation methods which have been practised are largely those of the natural gas producers themselves, with the very efficient assistance of the U. S. Bureau of Mines, which has effected a greater degree of coöperation between the natural gas producers and the oil men, which has been the stumbling block to the practical conservation of natural gas.

While the controversy in the courts between the people of Kansas and Missouri and the Kansas Natural Gas Co. has gone on without definitive results, there have been few other cases during the year where the industry has been hampered by very serious legislation. The development of utility commissions in various States, generally for the purpose of regulating prices to consumers, has done much to bring all natural gas distributors into the class of public utilities; and the fact that these companies have come to regard themselves in that light, has done much to increase coöperative work between the companies and the commissions. This is reflected in a remarkable address, at the recent annual meeting of the American Natural Gas Association, by Mr. A. C. Bedford, president of the Standard Oil Co. of New Jersey, who is a member of the National Council of Defense, in which he expressed his confidence in the ability of the National Gas Producers to coöperate on a large scale when, probably during the coming winter, the natural gas interests may be called upon to do their part in replacing coal and oil in industrial enterprises where the other fuels may be needed more directly in warfare.

The greatest development of natural gas resources consisted in exploiting every known field in the most thorough and economic manner, but new developments were also noted in Pike County, Indiana; in the Fox district north of the Healdton field in Oklahoma, where very large gas producers have established the great value of this field; in Texas, especially near Corpus Christi; and in Louisiana. In Kentucky gas has been found in quantities of possibly commercial value in Carter, Estill, Floyd and Lincoln counties. Special interest was shown in Wyoming as a natural gas producer. Not only the well-known gas wells of Byron, in the Basin country, contributed to the supply, but arrangements were completed and are in process of execution for utilizing natural gas from the Salt Creek field. Just after the close of the year the Jupiter Oil Co. in their search for oil found evidence of significant supplies of natural gas nearer to Casper than any other known supply. Near Baker, Fallon County, Montana, two wells with a total of 6,000,000 cu. ft. per day, were brought in and began supplying houses and industrial plants in the neighborhood.

PHOSPHATE ROCK

By W. H. Waggaman

In 1916 the phosphate industry continued to be greatly depressed on account of the world-wide war. While fairly accurate statistics of the production, exports and domestic consumption of the American phosphates are available, the data concerning the movements of foreign fertilizer materials are very incomplete.

The world's production of phosphate rock in 1913 before the European struggle began was over 6,780,000 tons. In 1916 (as far as can be learned at present) the production was only a little over half as great, namely, 3,712,992 tons. Of this amount the United States produced 2,177,292 tons (nearly two-thirds), marketed 2,285,126 tons, and consumed 2,081,467 tons. The total tonnage in 1916 shows a slight increase over that of 1915, when 3,573,301 tons was produced. This increase was due to a somewhat greater domestic consumption of the Florida pebble phosphate during the past year.

The falling off in the production of the various phosphate fields throughout the world during the past 3 years has been caused by one or more of the following factors: (1) The curtailment of exports due to closed ports, increased freight rates, and lack of boats; (2) the scarcity of labor in the foreign phosphate regions; (3) the consumption for other purposes of the sulphuric acid normally used in the production of acid phosphate.

The treatment of phosphate rock with sulphuric acid continues to be the nearly universal practice of rendering the phosphate rock soluble for fertilizer purposes, but the high cost of this acid has stimulated interest in other methods of producing soluble phosphate and it seems quite possible that before the war is over a scheme may be worked out which will successfully compete with the old method. In 1916 the consumption of raw rock phosphate for direct application to the field was 65,673 tons, which is a decided increase over 1915, when 51,101 tons was consumed.

Taking up the phosphate deposits in the order of their present commercial importance they are as follows: the phosphates of the United States, including those of great value and extent in Florida, Tennessee, South Carolina, and the Western States, Utah, Idaho, Wyoming, and Montana, and deposits of lesser importance in Kentucky, Arkansas, North Carolina and Virginia; the deposits in northern Africa in Tunis, Algeria, and Egypt; the deposits of the Pacific and Indian Oceans, including those of Ocean, Christmas and Pleasant Islands and the islands of the Marshall and Society Groups; the phosphates of Russia; the phosphates of Belgium and France; the Peruvian guano deposits, and the many smaller deposits in various other countries.

The world's production of phosphates is given in Table I.

TABLE I.—PRODUCTION OF PHOSPHATE IN THE WORLD
(In metric tons)

	1909.	1910.	1911.	1912.	1913.	1914.	1915.	1916.
Algeria	351,491	(*d*)319,069	332,897	388,515	461,030	(*e*)355,140	(*e*)225,891	(*e*)380,211
Augaur Palan Iseln.	9,000	45,000	41,000	50,000	90,000	(*e*)60,000	....	(*h*) 30,000
Belgium	205,260	202,880	196,780	203,110	(*e*)178,455	(*e*)10,988	(*c*)	(*c*)
Canada	998	1,341	506	149	349	866	197	184
Christmas Island (*d*).	197,982	310,625	250,000	300,000	(*f*)150,005	(*c*)	(*c*)	(*c*)
Dutch W. Indies								
Aruba	27,227	27,838	88,430	17,215	....	(*e*)86,572	....	....
Curacao	....	3,570	2,000	....	1,850	(*e*)11,219	(*e*)32,915	....
Egypt	1,000	2,397	6,425	69,958	101,311	71,945	82,998	(*e*) 21,000
France	397,903	333,506	312,204	330,000	335,000	....	....	....
French Guiana	8,997	6,816	....	....	....	....	....	....
Makatea (*d*)	....	....	12,000	40,000	82,000	....	....	....
Norway	1,364	903	....	....	....	....	....	....
Ocean Island	197,922	310,625	250,000	300,000	250,000	....	....	(*h*) 70,000
Russia	12,906	15,293	10,200	25,000	25,000	....	....	....
Spain	1,387	(*d*)2,840	3,520	3,292	3,548	....	9,080	....
Sweden	(*c*)	....	....	3,292	....	....	....	....
Tunis	1,223,512	1,286,262	1,446,633	2,057,498	2,284,678	1,427,161	1,389,074	1,034,489(*e*)
United States	2,503,186	2,724,849	3,260,626	3,216,046	3,068,604	2,752,971	1,873,625	2,177,292
Japan	3,781	1,042	2,271	7,849	19,047	38,252	57,723	....

(*c*) Statistics not available.
(*d*) Figures furnished by Charles Michel, Paris.
(*e*) Exports.
(*f*) *American Fertilizer.*
(*h*) Provisional figures.

United States

Since the amorphous phosphates of South Carolina were first exploited in 1868, the United States has been the foremost phosphate-producing nation in the world.

The famous Florida fields, the high-grade phosphates of Tennessee, and finally the vast deposits of phosphate in the Western States gives this country a known reserve supply greater than that of any other nation.

The following data (Table II) were collected with great care in 1913 and while the figures must be considered approximate they may also be regarded as conservative. Rock grading from 58 to 70 per cent. tricalcium phosphate is classed as high-grade and in the case of the low-grade phosphates in the West and the wash heaps of Florida the material is figured to its equivalent in high-grade rock.

TABLE II.—RESERVE SUPPLY OF PHOSPHATE ROCK IN UNITED STATES

	Tons.
Utah, Idaho, Wyoming and Montana:	
High grade	2,500,000,000
High-grade equivalent of all grades	7,500,000,000
Florida:	
High-grade equivalent of all grades	354,300,000
High-grade equivalent of wash heaps	20,000,000
Tennessee:	
High-grade equivalent of all grades	115,075,000
S. Carolina:	
High-grade equivalent of all grades	10,000,000
Arkansas:	
High-grade equivalent of all grades	20,000,000
Kentucky:	
High-grade equivalent of all grades	500,000
	10,519,875,000

While several million tons of rock has been mined since these figures were compiled, new discoveries of phosphate have been made which more than offset the quantity of rock consumed. Some later figures compiled by Phalen of the U. S. Geological Survey[1] place the total amount of marketable rock at 5,712,082,000 tons. These figures, however, do not take into consideration the phosphatic shales occurring in the Western deposits and the phosphate contained in the wash heaps of Florida.

The production, consumption, and exports of phosphate rock during the past 4 years are given in the following tables.

TABLE III.—PRODUCTION OF PHOSPHATE ROCK IN THE UNITED STATES
(In tons of 2240 lb.)

Phosphate.	1913.		1914.		1915.		1916.	
	Tons.	Value.	Tons.	Value.	Tons.	Value.	Tons.	Value.
Florida hard rock	510,811	$3,371,386	(a)309,689	$1,912,197	42,962	$231,995	81,071	$432,919
Florida land pebble	2,043,403	6,334,549	1,829,202	5,442,547	1,368,282	4,186,943	1,601,061	4,739,141
Florida river pebble	....	....	....	....	....	....	....	....
Total, Florida	2,554,214	$9,705,935	2,138,891	7,354,744	1,411,244	$4,418,938	1,682,132	$5,172,060
S. Car. land rock	109,333	$440,588	156,363	$496,907	78,543	$329,902	39,035	$147,552
S. Car. river rock	....	....	....	....	....	....	....	....
Total, S. Carolina	109,333	$440,588	156,363	$496,907	78,543	$329,902	39,035	$147,552
Tennessee	439,822	$1,649,303	451,942	$1,694,782	383,833	$1,063,217	454,515	$1,363,545
Other States	5,050	18,167	5,775	17,323	....	....	1,610	10,797
Total, U. S.	3,108,419	$11,813,993	2,752,971	$9,643,756	1,873,625	$5,812,057	2,177,292	6,693,954

(a) Reported by the U. S. Geol. Survey.

[1] W. C. Phalen, Phosphate Rock in 1915. *Min. Res. of U. S.*, part 2, U. S. Geol. Survey, pp. 227–244 (1916).

TABLE IV.—STATISTICS OF PHOSPHATES IN THE UNITED STATES
(In tons of 2240 lb.)

Year.	Production.	Imports.	Exports. (*a*)	Consumption.
1907	2,251,459	25,896	1,018,212	1,259,143
1908	2,375,031	26,734	1,196,175	1,205,590
1909	2,463,766	11,903	1,020,556	1,455,113
1910	2,681,938	19,319	1,083,037	1,618,220
1911	3,216,993	16,153	1,246,577	980,569
1912	3,166,032	28,821	1,206,520	1,988,333
1913	3,062,975	26,408	1,338,450	1,724,525
1914	2,752,971	15,078	928,992	1,839,057
1915	1,873,625	5,359	253,549	1,625,435
1916	2,177,292	4,612	203,659	2,081,467

(*a*) Neglecting the insignificant exports of foreign products.

The imports and exports of fertilizer materials of all kinds in the United States during the past 5 years are given in Tables V and VI.

TABLE V.—IMPORTS OF FERTILIZERS INTO THE UNITED STATES
(In tons of 2240 lb.)

	1912.		1913.		1914.		1915.		1916.	
	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.
Ammon. sulphate, tons	......	....	......	....	74,121	$4,475,603	32,447	$1,934,625	12,962	$954,815
Phosphates (crude), tons	20,685	$179,605	23,478	$184,204	15,078	136,526	5,359	50,606	4,612	36,389
Apatite, tons	80	1,140	2,930	22,515	20	300	*nil*	....	*Nil.*	....
Basic slag, tons	11,751	110,229	15,124	145,477	74,588	1,501,542	76	1,343	71	759
Blood char, lb.	......	....	2,954	333	(*b*)	....	(*b*)	....	(*b*)	....
Blood (dried)	......	220,297	......	86,065	(*b*)	....	(*b*)	....	(*b*)	....
Blood (dried) when soluble), lb.	7,701	423	6,412	339	(*b*)	....	(*b*)	....	(*b*)	....
Bone char, tons	......	20,414	......	12,484	(*b*)	....	(*b*)	....	(*b*)	....
Bone dust, tons	118,535	913,023	33,919	818,306	36,022	890,672	21,322	540,197	18,124	487,857
Guano, tons	34,856	685,140	16,461	313,898	25,562	762,688	9,974	220,860	12,997	378,109
Kainit, tons	479,417	2,400,590	466,184	2,349,689	329,611	1,550,879	6,674	95,440	36	1,173
Keiserite, tons	7,545	17,689	10,800	44,770	(*b*)	....	(*b*)	....	(*b*)	....
Cyanite, tons	900	7,535	612	7,949	(*b*)	....	(*b*)	....	(*b*)	....
Manure salts, tons.	185,682	1,824,426	172,557	1,798,973	168,426	1,842,649	13,947	207,674	1,104	21,273
Potash (muriate), tons	242,033	7 235,729	223,836	6,737,757	168,509	5,740,893	57,7742	2,297,149	1,161	348,961
Potash (sulphate), tons	50,551	1,853,236	48,022	1,798,369	36,246	1,568,704	11,344	663,399	1,514	381,684
Nitrate of soda, tons	481,786	15,427,904	586,315	20,713,375	543,715	15,223,671	772,190	22,959,997	1,218,423	38,131,962
All other fertilizers, tons	169,283	3,527,646	115,257	2,190,816	......	3,553,793	......	2,922,914	....	3,223,724

(*b*) Included in figures of all other fertilizers.

Florida.—In spite of considerable curtailment in its output, Florida continues to hold first place as the greatest phosphate-producing section in the world. Ideally located to supply the enormous demand for fertilizers in the Southern States and having easy access to ports for shipment abroad, these deposits will no doubt supply large tonnages to both the foreign and domestic markets for many years to come.

At the close of 1914, 23 companies were actively engaged in mining operations. In 1915, only 15 companies were so engaged. This number

TABLE VI.—EXPORTS OF FERTILIZER MATERIALS IN 1915 AND 1916

	1915.		1916.	
	Quantity.	Value.	Quantity.	Value.
Sulphur or brimstone, crude, tons	37,312	$724,679	128,755	$2,505,857
Phosphate rock, not acidulated:				
High-grade hard rock, tons	34,572	331,524	27,874	279,298
Land pebble, tons	218,620	1,269,789	175,561	705,755
All other, tons	357	4,326	224	2,330
All other fertilizers, tons	114,215	2,782,346	149,121	5,007,967
Exported to—				
Belgium	....	....	....	....
France	4,732	274,950	....	....
Germany	745	7,450	....	....
Italy	7,964	45,984	....	....
Netherlands	50,733	339,430	29,310	144,046
United Kingdom	79,044	443,210	58,327	218,167
Other Europe	118,715	943,071	166,650	1,016,554
Canada	40,987	822,944	38,364	762,248
West Indies and Bermuda	59,144	1,327,070	97,923	3,912,143
Japan	27	1,281	....	....
Other countries	5,633	182,595	2,390	113,750
Cottonseed meal, lb	165,710,192	2,296,349	204,594,620	3,458,519

was increased to 19 in 1916 but many of these only mined intermittently and few were working at their full capacity. The total production for 1916 was 1,682,132 tons. The amount marketed was 1,520,706 tons as against a marketed output of 1,411,244 tons in 1915.

The quantity consumed in the United States was 1,317,270 tons, which is a greater tonnage than has ever been marketed for domestic use, showing that the increased cost of sulphuric acid has not decreased the consumption of acid phosphate in this country.

Since practically all of their product has been heretofore shipped abroad, the operators in the hard-rock fields have suffered more by the European war than the producers of pebble phosphate. The closing of ports in Germany, a country which was one of the largest consumers of hard-rock phosphate, together with the enormous increase in ocean freight rates, has cut the foreign shipments of hard rock down to a minimum. In 1916 only six companies were engaged in producing hard-rock phosphate and none of these was mining at full capacity. The total amount produced during the past year was 81,071 tons, but only 34,402 tons was actually marketed as against 42,962 tons in 1915. The domestic consumption in 1916 amounted to 6528 tons. The remainder (27,814 tons) was exported to Europe and sold under a guarantee of 77 per cent. tricalcium phosphate. The average price of the rock f.o.b. ports was $5.34 per ton.

While the Florida land pebble phosphate is on the whole of somewhat lower grade than the hard rock (ranging from 70 to 75 per cent. tricalcium phosphate), the great extent of the pebble deposits and the facility with which they are mined makes the cost of production very low. Consequently the pebble phosphate is much more extensively mined than any other type of phosphate in this country. Although the European war has caused considerable curtailment in the production due to the cutting down of foreign shipments, the domestic consumption was actually

TABLE VII.—STATISTICS OF FLORIDA PHOSPHATE
(In long tons)

Year.	Production.			Total Shipments.	Domestic Consignment.	Exports.
	Hard Rock.	Pebble.	Total.			
1911..............	474,094	2,020,477	2,494,571	2,456,440	1,290,779	1,165,661
1912..............	536,379	2,043,486	2,579,865	2,422,932	1,219,927	1,203,005
1913..............	510,811	2,043,403	2,554,214	2,554,214	1,130,764	1,363,450
1914..............	309,689	1,787,597	2,138,891	2,138,891	1,209,898	928,993
1915..............	42,962	1,368,282	1,411,244	1,411,244	1,158,052	253,192
1916..............	81,071	1,601,061	1,682,132	1,520,706	1,317,270	203,435

greater in 1916 than ever before in the history of the industry. In 1915 the marketed output of pebble phosphate amounted to 1,368,282 tons. In 1916, 1,601,061 tons was produced, but only 1,486,304 tons was actually marketed. Of this amount 175,561 tons or a little less than 12 per cent. was exported.

The average price for the year was $2.96 f.o.b. ports, as against $3.06 in 1915.

The acquiring by the American Cyanamid Co. of the properties of the Amalgamated Phosphate Co. excited considerable interest among mine operators and fertilizer manufacturers in 1916. It is understood that the former company plans to increase greatly the output of phosphate and to produce concentrated fertilizer materials.

Tennessee.—There are three main types of phosphate occurring in Tennessee, which, taken up in the order of their present commercial importance, are the brown or Ordovician rock, occurring in Maury, Hickman, Giles, Davidson, Sumner, and Williamson Counties, the blue or Devonian phosphate occurring chiefly in Maury, Hickman, and Lewis Counties, and the white phosphate in Perry and Decatur Counties.

The brown-rock phosphate continues to be the most eagerly exploited of the three types. Improved methods of handling the rock have resulted in the recovery of much finely divided phosphate which was formerly lost. The life of the fields has therefore been considerably prolonged. The brown rock ranges in grade from 70 to 78 per cent. tricalcium phosphate, but most of it is sold under a guarantee of 72 per cent. tricalcium phosphate.

Blue-rock phosphate occurs as a bedded deposit normally overlain by a heavy black slate or shale. It is mined in a manner similar to a coal seam. The average grade is about 70 per cent. tricalcium phosphate.

Owing to the pockety nature of the deposits and the lack of transportation facilities, no white rock has been mined for several years. The rock varies between rather wide limits (70 to 85 per cent. tricalcium phosphate).

In 1916, 9 companies were engaged in mining Tennessee phosphate. Only one of these was producing blue rock, so the quantity of the two types is not separately stated. The total production in 1916 was 454,515 tons. The marketed output, however, was 506,104, of which 224 tons or 0.4 per cent., was shipped abroad. In 1915 only 383,833 tons was marketed from the Tennessee fields, so there was an increase of 68,109 tons during the past year. The average price of the rock f.o.b. mines was $3.00 per ton.

Further examination of the new field of phosphate discovered in eastern Tennessee[1] (Johnson County) has shown that it bears no relation to the deposits in the central portion of the State. The rock so far found is of too low a grade to prove of present commercial importance, except perhaps for local consumption.

South Carolina.—The nodular phosphates of South Carolina are far from exhausted, but the expense of mining and washing the rock, coupled with the fact that it is of a relatively low grade (60 to 61 per cent. tricalcium phosphate) when compared with the Florida and Tennessee product, has caused a gradual curtailment in the output from this State. The production in 1916 amounted to 39,053 tons, but the actual amount marketed, including part of the stock carried over from the previous year, was 53,047 tons. This was quite a reduction from the amount marketed in 1915, when 78,548 tons was produced. All of the rock was sold in this country and brought an average price of $3.78 per ton f.o.b. ports.

Utah, Idaho, Wyoming and Montana.—The deposits of Carboniferous phosphate in these four States are the most extensive ever discovered. The various beds range in thickness from a few inches to 6 ft. or more, with an average grade of about 70 per cent. tricalcium phosphate.

A great deal of phosphate occurs on Government land and in order to conserve these deposits for domestic use, large areas in the above States have been withdrawn from entry. Provision has been made, however, for the leasing of such lands on the payment of royalty to the Government. The withdrawals outstanding Jan. 1, 1916, according to the figures of the U. S. Geological Survey, were 2,660,136 acres in Florida, Idaho, Utah, Wyoming and Montana.

Claims had already been filed on much valuable land before any with-

[1] O. P. Jenkins, Phosphates and Dolomites of Johnson Co., Tennessee. *Res. of Tenn.*, April, 1916.

drawals were made, so several companies own, or control, very rich deposits of phosphate in Utah, Idaho and Wyoming, but up to the present time the limited use of fertilizer in the West and the heavy cost of hauling the material to a more ready market have prevented the development of these fields. The gradual tendency towards the production of more concentrated fertilizer materials, however, may lead to more energetic exploitation of the Western phosphates, since potential sources of power and sulphuric acid occur close to many of the deposits. Only one company reported any production from these fields in 1916 and this tonnage was small. The average price of the materials f.o.b. cars in Idaho and Wyoming is about $3.00 per ton.

What is apparently an extension of the Montana phosphate beds was discovered within the limits of Rocky Mountain Park near Banff, Alberta, Canada.

An investigation of this area by the Canadian Department of Mines,[1] however, has shown that the phosphate is of little economic importance at present. The main bed is only 12 in. in thickness with an average content of only 43.7 per cent. tricalcium phosphate.

Arkansas.—No production has been reported from Arkansas since 1912. The mines near Batesville have been shut down, as it has been found more practicable to supply the demand for phosphate just west of the Mississippi from the higher-grade deposits of Tennessee.

Kentucky.—Several small deposits of high-grade phosphate rock have been found in the Ordovician limestone in Woodford, Scott, Fayette and Jessamine Counties. The Kentucky phosphate occurs in thin close-grained plates, brownish-gray in color and resembling closely the brown-rock phosphate of Tennessee. Much of the rock will run 75 per cent. bone phosphate of lime.

Only one plant has so far produced any phosphate in Kentucky. A small production has been reported for 1916, which is included in the Tennessee statistics.

Phosphates in Foreign Countries

Africa.—The phosphates of Northern Africa including those of Tunis, Algeria and Egypt are next in importance to those of the United States. Whereas the material on the whole is not as high grade as that from Florida and Tennessee its nearness to the European market has made it a serious competitor of the American product for the export trade.

In 1916 the output from these three fields based on the material exported amounted to 1,435,709 tons, as against a production of 1,697,963 tons in 1915.

[1] H. S. de Shmid, *Bull.* 12, Dept. of Mines, Canada (1916).

Tunis.—Although the output of phosphate in Tunis has been considerably curtailed the exports in 1916 amounted to 1,034,489 tons as against exports of 1,100,000 tons and a production of 1,389,074 tons in 1915.

The largest single producer of phosphate rock in the world is the "Société des Phosphates de Gafsa," which owns or controls all the phosphate deposits in the vicinity of Gafsa, Tunis. A railroad 150 miles in length connects these deposits with the port of Sfax. The other companies operating in Tunis are the "Sociétés des Phosphates Tunisiens" and the "Campagnie des Phosphates du Dyr."

The Tunisian phosphate varies in grade from 58 to 63 per cent. tricalcium phosphate and the average price c.i.f. Mediterranean in 1916 was $7.20.

Algeria.—The Algerian phosphates while similar to those of Tunis have not been exploited to the same extent. In 1916 the exports amounted to 380,211 as against 225,891 tons in 1915, thus showing an increase of nearly 20 per cent. The average price was the same as that of the Tunisian product.

Four French companies are mining phosphate rock in Algeria, the most important being the "Campagnie des Phosphates de Constantine."

A considerable tonnage of acid phosphate is now being manufactured in Algeria, part of which is exported to Europe. The exports of this material in 1916 amounted to 1562 tons as against 1162 tons in 1915.

TABLE VIII.—SHIPMENTS OF PHOSPHATE ROCK FROM ALGERIA AND TUNIS
(In metric tons)

Year.	Algeria.	Tunis.	Year.	Algeria.	Tunis.
1896	142,524	....	1907	343,085	956,998
1897	227,870	....	1908	362,890	1,270,020
1898	269,572	....	1909	351,491	1,224,822
1899	286,681	65,209	1910	319,069	1,286,262
1900	277,896	171,288	1911(*a*)	332,897	1,446,633
1901	278,185	178,019	1912(*a*)	388,515	1,923,000(*b*)
1902	265,964	266,553	1913	438,601	1,984,880
1903	301,112	360,621	1914	355,140	1,427,161
1904	344,969	457,133	1915	225,891	1,087,816
1905	347,747	529,645	1916	380,211	1,034,498
1906	302,262	747,303			

(*a*) Figures furnished by Charles Michel, Paris. (*b*) Estimate.

Egypt.—Deposits of phosphate are now being exploited in Egypt, both in the Valley of the Nile and near the coast of the Red Sea. These deposits correspond in geological horizon to the phosphates of Algeria and Tunis and are probably an extension of those fields. The most important deposit is being developed by an English company on the Red Sea coast. In 1915, however, there was a considerable falling off in the output of Egyptian phosphate. While no figures are available showing the exact production for the past year, the exports amounted to only 21,000 tons as against 33,000 in 1915. Most of the rock was shipped to Great Britain and Japan.

Islands of the Pacific and Indian Oceans.—In certain islands in the southern Pacific and Indian Oceans deposits of phosphate occur which are of the highest grade yet discovered. The most important of these phosphate-producing islands of the Pacific Ocean are Ocean Island (English) of the Guilbert group; Tahiti and Makatea (French) of the Society group, Angaur (Japanese) of the Pellew group, and the Island of Naru (Japan) of the Marshall group. In the Indian Ocean Christmas Island near the west coast of Java contains an available supply of phosphate estimated at 8,000,000 tons.

Although there has been considerable mining activity on many of these islands during the past few years, the statistics concerning production and exports have been very meager. It is understood, however, that in 1916 the exportations to Japan from Ocean and Angaur Islands were 70,000 and 30,000 tons respectively.

Europe

Russia.—Large phosphate deposits which should prove of considerable commercial importance have been found in three regions in Russia. A geological survey conducted by the Moscow Agricultural Institute has revealed so far the existence of nearly 291,000,000 tons of phosphate rock. Up to the present time, however, there has been but little development of the phosphate industry in Russia. The bulk of the phosphate used is imported in the form of manufactured goods. According to reports received in the latter part of 1915 there were at that time only seven factories producing acid phosphate and but three producing basic slag.

The production of Russian phosphate rock for 1907–1913 is given in Table IX. Later statistics are not yet available. The imports of fertilizer materials to Russia during the past 5 years are given in Table X. The figures for 1916 are very incomplete.

TABLE IX.—PRODUCTION OF PHOSPHATE ROCK IN RUSSIA
(Metric tons)

Year.	Amount.	Value.
1907	11,290	$104,997
1908	14,786	137,510
1909	12,906	120,226
1910	15,293	142,225
1911	10,200	94,860
1912	25,000	....
1913	25,000	....

TABLE X.—IMPORTS OF FERTILIZERS TO RUSSIA

	1913, Poods.	1914, Poods.	1915, Poods.	1916, Poods.
Mineral Phosphorites	3,800,000	1,239,512(a)	....	....
Other Nat. Fertilizers	5,000,000	....	....	....
Crude Ground Bones	154,089	16,900(a)	10,024	307
Ground Thomas Slag	11,366,463	7,105,427(a)	(b)199,260	....
Superphosphates	12,000,000	7,214,940(a)	7,471,819	1,286
Roasted Bones	....	....	....	....
Stassfurt Salts, German	4,700,000	....	15,050	....
Chloride of Potassium	....	....	....	(d)122
Chile Saltpeter	1,000,000	3,233,008	(b)1,790,220	(c)1,597,173

(a) Jan. to Oct., 1914. (b) First 11 months. (c) First 11 months. (d) Sulphate and chloride.

France and Belgium.—At one time Europe's main supply of phosphate rock was obtained from the deposits occurring in Tertiary and Cretaceous rocks in northern France and southwestern Belgium. Not only have many of these deposits been nearly exhausted, but when compared with the phosphate of the United States and northern Africa the rock is of a rather low grade (50 to 55 per cent. $Ca_3(PO_4)_2$). The exploitation of these deposits therefore had largely dropped off even prior to the war. At present much of the phosphate area is under German control, so no statistics have been available for the past 2 years.

As importers of raw phosphates and producers and exporters of acid phosphate and basic slag, France and Belgium have been very active.

The imports and exports of these two countries as far as could be learned are given in Tables XI and XII.

TABLE XI.—FRENCH IMPORTS AND EXPORTS OF PHOSPHATE ROCK
(In metric tons)

Year.	Imports.	Exports.
1912	903,489	22,062
1913	934,688	21,128
1914	(a)647,769	11,219
1915	(b)325,114	(b)1,796
1916	285,906	1,437

(a) 10 months. (b) Provisional figures.

TABLE XII.—BELGIAN IMPORTS AND EXPORTS OF PHOSPHATE ROCK
(In metric tons)

Year.	Imports.	Exports.
1912	244,221	22,916
1913	244,765	18,158
1914	(a)113,668	(a)10,988
1915	....	....

(a) First 6 months of 1914.

TABLE XIII.—BELGIAN IMPORTS AND EXPORTS OF BASIC SLAG
(In metric tons)

Year.	Imports.	Exports.
1912	130,439	550,841
1913	144,553	685,907
1914	(a)76,248	(a)335,016
1915	....	....

(a) First 6 months of 1914.

It is reported that two pockets of phosphate rock were recently discovered by a French soldier in the trenches before Picardy.[1] The grade of the rock is not stated.

Germany.—Since the confiscation of its insular possessions by England and Japan, Germany has no phosphate deposits except those of minor importance which may be in its possession in France and Belgium. Up to the time of the war Germany imported an immense tonnage of phosphate rock from the United States and Tunis. While both of these sources of supply have been cut off, the demand for phosphatic fertilizers can be partly met by the production of basic (phosphatic) slag, of which Germany has normally been a large exporter. The output of this material has no doubt greatly increased due to the greater consumption of iron and steel. No statistics have been available concerning the phosphate industry in Germany since 1914.

The imports of phosphate to Germany for 1911–14 inclusive are given in Table XIV and the imports and exports of slag in Table XV.

TABLE XIV.—IMPORTS OF PHOSPHATE INTO GERMANY
(Metric tons)

Imported from	1911.	1912.	1913.	1914.
United States	378,770.4	342,646.3	421,212	420,163(a)
Algeria	164,691.9	190,747.9	107,405	
Tunis	62,267.1	115,206.1	108,707	
Belgium	91,265.9	63,011.0	53,433	
Christmas Islands	63,778.6	52,015.9	70,467	
Australia	20,804.3	49,248.1	18,866	
German Australasia	17,005.3	44,257.7	....	
France	15,681.9	40,686.4	19,529	
Other countries	18,994.2	5,024.8	4,129	
Total	833,259.6	902,844.2	803,748	
Total value	$9,915,794.0	$10,743,796.0	$8,664,953	

(a) First 6 months of 1914.

TABLE XV.—GERMAN IMPORTS AND EXPORTS OF BASIC SLAG
(In metric tons)

Year.	Imports.	Exports.
1912	372,835	663,024
1913	441,069	713,878
1914	(a)234,081	(a)307,106

(a) First 6 months of 1914.

[1] *L'Echo des Mines*, Sept. 3, 1916.

England.—Low-grade phosphate in the form of coprolites has been found in various parts of the British Isles, but not in sufficient quantities to prove of commercial importance. In several of its insular possessions and in Egypt, however, England controls important sources of phosphate rock. England also produces a large tonnage of basic slag.

The imports and exports of fertilizer materials for the past 4 years are given in Tables XVI and XVII.

TABLE XVI.—IMPORTATIONS OF PHOSPHATE MATERIALS TO ENGLAND
(Metric tons)

Material.	1913.	1914.	1915.	1916.
Basic slag	(a) 43,403	16,838	....	....
Guano	17,285	39,915	(b) 27,159	21,991
Phosphate rock	486,989	564,521	(b) 380,651	338,721
Total	547,677	621,274	407,810	360,712

(a) First 11 months. (b) Includes Ireland.

TABLE XVII.—EXPORTATIONS OF PHOSPHATIC MATERIALS FROM ENGLAND
(Metric tons, 11 months)

Material.	1913.	1914.	1915.	1916.
Superphosphate	(a) 61,416	67,111	(b) 69,838	14,760
Phosphate rock	11,808	2,646	....	....
Basic slag	(a) 157,207	134,808	(b) 119,373	39,248
Total	230,431	203,565	189,210	54,008

(a) First 11 months. (b) Includes Ireland.

Spain.—No production of phosphate has been reported from Spain since 1912, when 3892 tons of low-grade material was produced. It has been reported, however, that Spain now offers a good market for American fertilizer materials.[1]

The imports of phosphatic materials to Spain for the past 4 years are given in Table XVIII. It will be noticed that the imports of phosphate rock in 1916 were greater than ever before.

TABLE XVIII.—IMPORTS TO SPAIN (a)
(In metric tons)

Material.	1913.	1914.	1915.	1916.
Phosphate rock	254,463	(b) 163,921	212,085	288,328
Basic slag	....	....	....	....
Superphosphate	149,602	(c) 116,897	(c) 63,013	(c) 23,115
Guano	1,781	(b) 2,382	946	1,281

(a) Figures obtained from Le Movement Int. des Engrais Chimiques, Rome. (b) January to October. (c) Includes basic slag.

[1] *Comm. Rept.*, p. 787, Aug. 14, 1916.

South America

Peru.—The deposits of guano on islands just off the Peruvian coast have been important sources of nitrogen and phosphoric acid since 1842. These deposits are chiefly derived from the droppings of myriads of sea birds and although millions of tons have been exported, the deposits should last indefinitely provided care is exercised in mining the material and the birds are not interfered with during the breeding season.

The "Peruvian Corporation, Ltd." has been exploiting these guano deposits since 1890. Most of their output has been shipped abroad.

The local demand for guano has been very much greater in recent years than the amount supplied and the Peruvian Government, feeling that the agricultural interests of the country were suffering, passed a law in 1915 which gives the national agriculturists a preferential right over a certain tonnage of guano. The Peruvian Corporation, Ltd., has been trying to bring about a reversal or modification of this law, since its privileges have been seriously curtailed thereby.

No statistics on production, consumption and exports of Peruvian guano have been obtained since 1914. The consumption of guano in Peru from 1909 to 1914 is as follows:

	Tons.		Tons.
1909–10	26,220	1912–13	36,592
1910–11	25,083	1913–14	38,787
1911–12	39,456		

TABLE XIX.—PRODUCTION AND EXPORTATIONS OF PERUVIAN GUANO
(In metric tons)

	1912.	1913.
Production	72,305	74,337
Exportations	38,633	37,530

Argentina and Uruguay.—Argentina and Uruguay, while possessing no deposits of phosphate rock, normally export a considerable tonnage of bones and guano. The exports, however, have fallen off since 1914 owing to high freight rates and lack of carriers.

The exports for the past 3 years as far as could be learned are given in Table XX.

TABLE XX.—EXPORTS OF BONES AND GUANO FROM ARGENTINA AND URUGUAY

	1914.		1915.		1916.	
	Guano.	Bones.	Guano.	Bones.	Guano.	Bones.
Argentina	21,972	32,479	19,496	16,519	(*a*)	5,223
Uruguay	5,662	7,729	1,435	7,729	(*a*)	(*a*)

(*a*) Statistics not available.

Asia

Japan.—Up to the time of the European war, Japan possessed no phosphate deposits of importance except those on Rasa Island at the extreme end of the Loochoo group. The amount of phosphate on this island is estimated at 2,800,000 tons, but the material is said to be so high in oxides of iron and aluminium as to render it hardly suitable for acid treatment.

Most of the phosphate rock used in Japan is imported from the United States and Egypt. But the confiscation of the Islands of Angaur and Naru (formerly German possessions) should enable Japan to supply a large part of her demand from the high-grade deposits of these islands.

The production of phosphate rock on Rasa Island amounted to 50,000 tons in 1915 as against 28,022 tons in 1914. The imports of phosphate from various countries for the past 5 years are given in Table XXI.

TABLE XXI.—IMPORTS OF PHOSPHATE ROCK TO JAPAN

Country.	1912.	1913.	1914. (*a*)	1915.	1916.
England	....	21,990	(*b*)	135,800	(*c*) 89,995
France	....	....	....		
United States	74,700	38,740	54,063		
Egypt	10,220	29,700	68,157		
Other countries	198,000	238,150	144,702		

(*a*) From January to September, 1914. (*b*) Included in figures for other countries.
(*c*) First 11 months.

China.—No production of phosphate has been reported from China, but it has been stated that deposits of phosphate occur on the Pratas Islands, 170 miles south of Hong Kong. A Chinese company, the "Tony Sartou and Pratas Islands Phosphate Syndicate," has obtained concessions to work the deposits, which are estimated to contain 900,000 tons.

West Indies

Several islands in the Caribbean Sea (notably Curacao and Aruba) contain phosphate deposits of excellent quality. In October, 1913, mining was resumed on the Island of Curacao after a suspension of 20 years. A total of 1850 tons was produced from the island in 1913. No figures have yet been obtained for 1914, 1915 or 1916. An English company was mining the rock, which is of exceptionally high grade, containing from 80 to 85 per cent. bone phosphate of lime and less than 1 per cent. of the combined oxides of iron and aluminium.

Technology

The problem of producing soluble or available phosphates without the use of sulphuric acid is receiving an ever increasing amount of attention. This is due not only to the great demand for sulphuric acid in the manufacture of munitions of war and a consequent enormous rise in the price of this acid, but also to the fact that there is a growing tendency toward the use of more concentrated fertilizer materials in the production of higher-grade mixed fertilizers.

If it were not for the fact that the fertilizer companies had their own sulphuric-acid plants, the use of this acid for the manufacture of superphosphate would hardly be commercially possible; but in order to hold their trade these companies are still consuming much of their acid in the production of soluble phosphates when they could sell it for munition purposes at a considerably greater profit.

Gray's Process.[1]—This process consists in producing phosphorus and phosphorus compounds of various metals by smelting in a blast furnace a mixture of the metal-bearing ore, phosphate rock, silica and coke. The metal with its high content of phosphorus is tapped off in the ordinary way and used for the manufacture of special alloys. The excess of phosphorus distils over and is collected under water or in some other suitable manner.

Bassett's Process.[2]—H. P. Bassett proposes to treat potash feldspar with acid sodium sulphate at an elevated temperature. The potash he claims is thus rendered soluble and the fumes of sulphur dioxide and trioxide which are evolved are then led over phosphate rock which is also converted into a water-soluble form. The inventor shows a preferred type of apparatus in which to carry out his process.

Process for Preparing a Concentrated Fertilizer.[3]—Ross, Merz and Carothers, scientists in the U. S. Department of Agriculture, have invented a process for preparing a concentrated fertilizer material without resort to expensive filtration and evaporation.

The scheme consists in allowing gaseous ammonia to act upon fumes of phosphoric anhydride in the presence of water vapor. The resulting product when cooled is a solid which may consist of one or more of the following compounds depending on the quantity of water vapor present:

$$P_2O_5 + H_2O + 2NH_3 = 2NH_4PO_3$$
$$P_2O_5 + 2H_2O + 2NH_3 = (NH_4)_2H_2P_2O_7$$
$$P_2O_5 + 3H_2O + 2NH_3 = 2NH_4H_2PO_4$$

[1] U. S. Patent No. 1,168,495 (1916).
[2] U. S. Patent No. 1,172,420 (1916).
[3] U. S. Patent No. 1,194,077 (1916).

Newberry and Fishburne's Process.[1]—These inventors have patented a number of processes for the production of citrate soluble phosphoric acid from natural phosphates, but their most recent scheme consists in heating to a sintering temperature in a rotary kiln a mixture of phosphate rock, sodium carbonate and limestone. The following procedure, it is claimed, gives excellent results:

1. Grind the phosphate rock to fine powder.
2. Add an amount of sodium carbonate approximately equal to one-half of the phosphoric acid in the charge of rock.
3. Add a quantity of limestone equal approximately to one and one-half times the silica present in the charge of rock.
4. Calcine the mixture at nearly white heat to the point of semi-fusion.

The charge is calcined in a rotary cylinder lined with some basic refractory material.

Bishop's Process.[2]—The invention of E. S. Bishop, which has for its object the production of soluble or available phosphoric acid, has been assigned to the Armour Fertilizer Co. The process consists in subjecting to a sufficiently high temperature in the presence of steam a mixture of a metal chloride and phosphate rock with an excess of silica sufficient to combine with the metal of the chloride and part of the calcium of the phosphate rock.

When using potassium chloride the production of dicalcium or citrate soluble phosphoric acid may be represented thus:

$$Ca_3(PO_4)_2 + 2SiO_2 + 2KCl + 2H_2O = Ca_2H_2(PO_4)_2 + 2HCl + K_2SiO_3 + CaSiO_3$$

By increasing the proportion of potassium chloride it is claimed that mono-calcium or water-soluble phosphoric acid is produced thus:

$$Ca_3(PO_4)_2 + 4SiO_2 + 4KCl + 4H_2O = CaH_4(PO_4)_2 + 4HCl + 2CaSiO_3 + 2K_2SiO_3$$

The temperature of the mass must not be allowed to rise very high, since phosphoric acid would thus be lost through volatilization.

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[1] U. S. Patent No. 1,194,219 (1916).
[2] U. S. Patent No. 1,204,238 (1916).

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PLATINUM

By George F. Kunz

The year 1916 and the early part of 1917 have been the most unusual that have ever been experienced in the platinum world. Owing to the partial cessation of mining—due to several reasons, the most important being the conscription of miners for the Russian army—the yield of platinum was reduced to one-third. The absorption by the munitions plants of an immense quantity, possibly 100,000 ounces, seriously aggravated the situation. And, finally, the action of the allied powers in forbidding the shipment of platinum to the United States—and, in fact, its exportation to any country—for fear it would come into the hands of the enemy, unless guarantees were given that the material was to be used for special governmental purposes, resulted in the locking up of 100,000 ounces, if not more, in England, France and Russia.

The increasing scarcity led to an effort on the part of the chemists to attempt the prevention of the use of platinum for jewelry—although no other metal exists that will give the same effect—first, by appeals to the government; and second, by an effort to impose a duty of 250 per cent. on the value of platinum itself. The Honorable William C. Redfield, Secretary of Commerce, made an exhaustive examination in connection with the United States Geological Survey, who had assigned Dr. J. W. Hill to this special work. After a conscientious investigation they both agreed that there was no necessity to commandeer the platinum of the jewelry trade, and in return the jewelers promised to safeguard the use of platinum, employing it only in the mounting of jewels and the lighter forms of jewelry, so as to restrict as much as possible an unnecessary consumption of this valuable material.

The United States supply of platinum is discussed as follows in the Geological Survey *Press Bulletin:*

The known supply of metals of the platinum group in the world is possibly 5,000,000 oz., of which it is within reason to say that the stock of platinum amounts to 4,000,000 oz. Estimates based on the official figures of production from Russia since 1843, which are taken as 25 per cent. too low, and on the assumption that Russia has supplied 95 per cent. of the world's output, indicate that the total quantity of crude placer platinum produced in the world since 1843 has been less than 4,632,000 troy oz., or about 159 short tons.

From the most reliable information in the hands of the United States Geological Survey, Department of the Interior, it is estimated that the total quantity of platinum in the United States is about 1,000,000 oz., besides which there is over 400,000 oz. of other metals of the platinum group, principally palladium, iridium, and rhodium.

The Russian situation is very difficult, but it is known that there are considerable stocks of crude platinum held in Russia which are available to the Allied governments. It is believed that the production from Russia in 1917 will be considerably increased, perhaps equaling the 1915 output.

Apparently the normal requirements of platinum in the United States call for 165,000 oz. a year, part of which is supplied by refining scrap and sweeps from the various industries using platinum. It is estimated that the dental industry formerly used between 25 and 30 per cent. of the supply, part of which can not be considered as recoverable. However, dental manufacturers are now using a number of alloys in place of platinum. It is estimated that the jewelry industry uses between 40 and 50 per cent. of the supply, practically all of which would be recoverable if necessity arose.

There is no available information concerning the quantity of platinum in chemical utensils in the many hundred laboratories throughout the United States, but it is probably not much over 10 or 15 per cent. of the supply and is all recoverable.

In 1915 about 44,000 oz., or 4 per cent. of the apparent United States stock of platinum, was used in contact-process sulphuric-acid works. The acid made in these plants is very strong, and its use at this time is limited practically to munition makers. The production of sulphuric acid or grades in use in ordinary chemical industry does not depend on catalytic platinum, as such acid is made in lead chambers. The output of contact-process plants has increased nearly 200 per cent. since 1915, and it is understood that plants using this process are not yet operated to their full capacity. It therefore would not appear that there is any pressing need for a large supply of platinum by the sulphuric-acid industry.

The Government laboratories are apparently well supplied with platinum utensils, and are not in the market for platinum at present, except as investigations on a larger scale may require new equipment. The United States mints are known to refine platinum and doubtless have stocks sufficient to meet any immediate governmental requirements.

A census of stocks of unmanufactured platinum in the United States that can be considered as immediately available is now being taken by the United States Geological Survey. From the information already available it would appear that there are supplies of platinum sufficient to meet such extensions of contact-process plants as may be required immediately, and a surplus left for all ordinary requirements, but it should be emphasized that new demands may arise at any time which the present stocks of platinum in this country could not meet.

All the known placer deposits that contain platinum are near areas of basic igneous rocks, and it would seem that the first step in any search for new deposits of platiniferous gravels is to look for outcrops of peridotite, pyroxenite, dunite, and serpentine. When areas of these rocks have been found the gravels of the streams that rise in them should be washed to see whether they contain platinum. Most of the heavy concentrates found in gravels that carry platinum are rich in chromite and olivine. The character of the rock of which the gravels were formed may give a clue to their source.

The falling off in the Russian output of platinum continues, and it is estimated that not over 2115 kg. or about 68,000 troy oz., will represent the amount won in 1916, against 3726 kg., or 119,789 troy oz. in

1915, and approximately 4880 kg., or 157,182 troy oz. in 1914.[1] The scarcity of labor and the difficulty in replacing any damaged parts of dredges are represented to be chief causes of the lessened production.

The check to Russian production coupled with an increased demand has stimulated the search for old platinum material, so that while the average annual sales of "scrap" platinum in the United States have been about 1244 kg. (40,000 troy oz.,) those for 1916 rose to 1536.5 kg. (49,400 troy oz.). The refiners of copper and gold bullion in 1916 furnished 79.7 kg. (2556 oz.) of platinum besides 85.4 kg. (2746 oz.) of palladium.

Early in January, 1917, a circular letter from the British authorities was received by all the wholesale jewelers in London informing them that they must neither sell nor buy platinum. The retailers were not specially instructed, but a similar paragraph in the official gazette was deemed sufficient notice for them. Since that time many of those interested have had interviews with the authorities, and were told that they might accept orders for mounting, etc., but pending permission must not deliver anything. It is not believed that there will be any serious interference with the retail business. While there does not appear to be any actual shortage of the material, the Government, whose needs are large and progressive, is making sure that so far as it is concerned conditions will remain constant.

Prices

The main cause for the abnormally high price of platinum today, apart from the intensified use of it in connection with munition work, and its use in jewelry, must be sought in the embargoes put upon its exportation by the belligerent countries of Europe in 1915. Since then there have

AVERAGE PRICES OF PLATINUM
(In dollars per troy ounce)

	1915.			1916.		
	New York Refined Platinum.	Russia, 83 Per Cent. Petrograd	Crude Metal Platinum Ekaterinburg.	New York Refined Platinum.	Russia, 83 Per Cent. Petrograd.	Crude Metal Platinum Ekaterinburg.
January	41.10	....	....	90.05	61.25	61.10
February	40.00	30.38	30.08	90.00	61.14	62.625
March	39.50	30.38	30.08	90.75	....	....
April	38.63	30.38	30.08	83.10	63.70	63.70
May	38.50	30.57	30.08	80.50	66.64	65.92
June	38.00	32.39	31.02	78.13	63.70	63.92
July	38.00	32.39	31.02	63.60	63.21	63.92
August	39.25	32.30	30.72	62.56	67.41	66.45
September	50.00	....	....	84.25	67.41	66.45
October	54.50	37.98	38.70	89.75	77.42	71.44
November	62.63	47.46	46.64	101.25	....	....
December	85.50	56.40	56.25	86.87	....	....
Year	47.13	....	....	83.40	....	....

[1] *Min. Mag.*, Mar., 1917.

been no exports of this metal for use in the arts from England, France, Germany, or Russia, the shipments received here having been consigned to munition makers for exclusive use in the manufacture of munitions and explosives. A small amount not subject to such restrictions has been received from Colombia. This accounts for the phenomenal rise in prices, up to $100 or even $105 per oz., a figure that makes platinum worth five times its weight in gold.

AVERAGE MONTHLY PRICES OF PLATINUM AT NEW YORK
(In dollars per troy ounce)

	1906.	1907.	1908.	1909.	1910.	1911.	1912.	1913.	1914.
January......	20.50	38.00	25.50	24.10	29.00	39.06	46.00	45.50	43.38
February.....	25.00	38.00	25.50	24.00	28.75	39.31	45.63	45.50	43.50
March........	25.00	37.00	25.50	23.75	29.13	41.00	45.50	45.50	43.50
April..... ...	25.00	32.50	23.50	23.50	29.25	41.35	45.50	45.50	43.50
May..........	25.00	29.50	22.50	23.25	29.55	42.81	45.50	45.50	43.50
June.........	25.40	26.20	23.50	22.75	31.38	42.88	45.50	45.50	43.50
July..........	26.00	26.75	20.00	22.43	33.00	42.95	45.50	45.50	43.50
August.......	26.00	28.13	18.75	22.65	33.00	44.38	45.50	44.90	50.20
September....	32.10	28.70	20.00	25.31	33.63	45.31	45.50	43.96	50.00
October......	33.00	27.13	21.50	27.75	37.50	46.25	45.50	44.00	49.50
November....	35.50	26.31	24.00	29.50	39.44	46.13	45.50	43.70	45.45
December.....	38.00	26.00	24.00	29.50	38.75	46.00	45.50	43.45	42.19
Year.....	28.04	28.18	22.85	24.87	32.70	43.12	45.55	44.88	45.14

The platinum situation is not so tense at the present writing, for in the month of May, 1917, the French Government permitted the exportation of 350 oz. to a platinum dealer at $102 per oz.

There are at the time of writing 800 poods of platinum held in Petrograd at $82 per oz. ($2.64 per gram), to be released upon proper authorization from any of the Allied governments. The cause of the advance of platinum to over $100 per oz. may have been due to two reasons: first, the use of platinum in munition chemistry; and, second, the reduction of the Russian production, owing to conscription, which resulted in not more than one-third to one-half of the number of men usually employed in platinum mining being left to their tasks. Hence, a great demand for munition works, and a lower yield through a scarcity of labor, have been the principal contributory causes to the so-called "platinum situation." It is possible that the moment hostilities may cease, platinum prices will return to the former level or even lower, as munition plants will not need new supplies, and may release some of the great quantities that they are using.

Nothing can serve to emphasize more thoroughly the change in platinum values in the past 25 or 30 years than the fact that a price of $16 per troy oz. (about 50 cts. per gram) was regarded as extremely high in 1890. What was considered to be a phenomenal rise was attributed to the purchase of an immense quantity of scrap platinum by the London dealers, Messrs. Johnson, Matthey & Co. and Des Montis, Le Brun & Co. As these firms had been credited with a purchase of 500,000 oz. (15,551.75 kg.) the price was forced up and much old platinum brought into the market. Soon, however, a sharp reaction set in, and by 1891 platinum was worth but $9.50 per oz. or about 30 cts. per gram.[1]

Platinum in the United States

It is estimated, on fairly complete returns, that domestic refiners treated in 1916 about 488 oz. of domestic crude platinum (74 per cent. pure) producing therefrom 172 oz. of platinum, 84 oz. of iridium and 113 oz. of iridosmine. In addition to this native product, 10,118 oz. of crude platinum from South America (about 88 per cent. pure) was refined. Crude placer platinum, domestic and foreign, furnished 8943 oz. of platinum, 235 oz. of iridium, 199 oz. of iridosmine, and 18 oz. of palladium. The refiners of copper and gold bullion produced 2556 oz. of platinum, 100 oz. of iridium, and 2746 oz. of palladium, about half of the material treated being of domestic origin. This shows a production (including material of foreign origin, except Colombian crude) of about 11,500 oz. of platinum, 335 oz. of iridium, 200 oz. of iridosmine, 2764 oz. of palladium.[2]

STATISTICS OF PLATINUM IN THE UNITED STATES

Year.	Production. (a)		Imports.			Total.
			Unmanufactured.		Manufactured.	
	Troy Oz.	Value.	Troy Oz.	Value.	Value.	Value.
1900	400	$ 2,500	118,919	$1,728,777	$ 36,714	$1,767,991
1901	1,408	27,526	85,438	1,673,713	24,482	1,725,721
1902	94	1,814	105,450	1,950,362	37,618	1,989,794
1903	110	2,080	114,521	1,921,772	135,889	2,059,741
1904	200	4,160	103,802	1,812,242	105,636	1,922,038
1905	318	5,320	104,196	1,985,107	188,156	2,178,583
1906	1,439	45,189	137,556	3,601,021	187,639	3,833,849
1907	357	10,589	74,208	2,509,926	175,651	2,696,166
1908	750	14,350	50,768	1,096,615	134,119	1,245,084
1909	638	15,950	118,851	2,557,574	410,997	2,984,521
1910	773	25,277	120,478	3,320,699	333,965	3,679,941
1911	940	40,890	122,390	4,722,752	135,842	4,899,484
1912	1,005	45,778	104,683	4,334,488	159,995	4,540,261
1913	1,034	46,530	117,947	4,938,706	105,553	5,090 789
1914	3,430	154,350	72,267	2,934,580	39,143	3,128,073
1915	6,495	322,347	61,437	2,340,476	71,532	2,734,355
1916	24,518	2,044,801	53,484	3,138,396	18,923	5,202,120

(a) Statistics of the U. S. Geol. Surv. Recovered by refiners.

The main sources of the platinum ore recovered in the United States in 1915 were the California placer mines in Butte, Humboldt, Plumas, Sacramento, Stanislaus, Trinity and Yuba Counties, where over 600

[1] *Min. Res. of U. S.*, 1882, p. 144.
[2] *Comm. Rept.*, Apr. 18, 1917.

oz. of crude platinum was produced. The single producing source in Oregon was a beach deposit in Curry County, although its presence has been ascertained in several beach deposits along the coast as well as in the neighborhood of Kerby, Josephine County.

Apart from the placer fields of northern California and of southwestern Oregon, whence the largest quantity of crude platinum is obtained in the United States, there are at least three other primary localities, according to the annual report of the Secretary of the Interior for 1915. These localities as noted by Secretary Lane are: the Rambler mine in Albany County, Wyoming; the Boss mine in the Yellow Pine district of Clark County, Nevada, and the Great Eastern mine, about 25 miles northeast of Moapa, in the same county.

The characteristics of the platinum, osmiridium and iridium found in Curry Co., Oregon, have been thus described:[1]

The platinum has a bright metallic luster and is usually steel-gray in color, although lighter tints are sometimes found, and silver-white platinum is not unknown. It usually occurs in tiny scales which are malleable and sectile. Some of the metal is magnetic, although this is not always the case. In fact the Curry County platinum rarely appears to be as magnetic as is the magnetite with which it is associated, and magnetic methods may frequently be used to separate the two. The osmiridium (iridosmine) differs from the platinum in being considerably harder (will scratch glass), rather brittle, silver-white (usually) in color, and in its tendency to occur in hexagonal scales. The iridium is as hard as the osmiridium, and, like it, is rather brittle. Fractured surfaces are, however, apt to be gray, although the color on the outside is usually silver-white with a slight yellowish tint. It is more apt to occur in angular grains than in scales. The writer concludes by advising prospectors always to keep platinum in mind, especially when they are investigating the placer deposits of streams draining serpentine areas.

In the Boss mine, Clark County, Nevada, there has been installed the first unit of a chloridizing-leaching plant by which 10 tons of ore can be treated daily. The average amounts of precious metals recovered from a ton of the ore are: copper, 4 per cent.; gold, 31.1 grams; silver, 62.2 grams; platinum and palladium, 46.65 grams. Similar ore to this is found in the Oro Amigo mine.[2]

The shortage of platinum has greatly stimulated the search for it in the metallic deposits in various parts of the country. The chief chemist of the Burnhart Laboratories of Denver, Mr. A. Lynn de Spain, states that platinum is to be found in the auriferous gravels of the Iron Hill

[1] *Min. Res. of Ore.*, Oct., 1916, pp. 67, 68.
[2] *Eng. Min. Jour.*, Jan. 6, 1917.

placer at Como, Colo. It has unquestionably been discovered in the black sands of Clear Creek in the same State.[1]

A new source of platinum is reported in the holdings of the Roll Call Mining Co., near Villa Grove, Colo. Assays made of material extracted from a 2-ft. vein, 410 ft. distant from the entrance to the company's tunnel, show the following values and quantities in a ton: gold, $3.20, platinum 158.32 grams (5.09 oz.), silver, 94.86 grams (3.05 oz.), and 3.5 per cent. copper. This makes an ore value of $500 per ton. Until a recent assay the presence of platinum here was entirely unsuspected; the deposits came from a depth of 1400 ft. beneath the surface workings.[2]

World's Production

On account of the continued falling-off in the Russian output, the world's production of platinum in 1916 was only about one-third of the annual production before the war. The total in 1911 and in 1912 approximated 315,000 oz. each year. The following table, largely from estimates by the U. S. Geological Survey, gives the approximate production from 1913 to 1916.

WORLD'S PRODUCTION OF NEW PLATINUM IN 1913-1916, BY COUNTRIES
(In troy ounces)

Country.	1913.	1914.	1915.	1916.
Russia, crude	(a)250,000	(a)241,200	(a)124,000	(a)63,900
Canada, crude (b)	(a)50	(a)30	(a)100	(a)60
New South Wales and Tasmania, crude (c)	1,275	(a)1,248	303	222
Colombia, crude	(a)15,000	(a)17,500	18,000	25,000
United States, domestic crude	483	570	742	750
United States, refined from foreign and domestic matte and bullion (d)	(d)1,100	2,905	5,753	2,556
Borneo and Sumatra and other crude (e)	200	(f)	(f)	(f)
Total	268,108	263,453	148,898	92,488

(a) Estimated. (b) In addition to platinum contained in matte and bullion refined in the United States. (c) Chiefly iridosmine. (d) Does not include refined platinum from domestic crude. (e) Includes small production in Madagascar. (f) No basis for estimate.

Canada.—Placer mining for platinum in the Tulameen region has been quite active, but on a small scale, and the production of the metal from this source is small. However, it is believed to be considerably larger than Canadian Department of Mines reports would show, since much of the ore is shipped directly to American refineries. In 1915 about 100 oz. of crude platinum is said to have been thus shipped.

The Department reports a total production for the Dominion of 23 oz. in 1915 and 15 oz. in 1916. The customs report, which includes the platinum shipped in "concentrates and other forms" gives exports for the

[1] *Met. Chem. Eng.*, Mar. 1, 1917.
[2] *Salt Lake Min. Rev.*, Mar. 15, 1917.

fiscal year 1916 of 430 oz. domestic, valued at $32,827, compared with 399 oz. at $25,426 in 1915.

The Sudbury nickel-copper ore in Ontario forms a source of both platinum and palladium, and this also is recovered in the United States, by the International Nickel Co. The extremely small percentage of platinum and palladium contained in the ore is indicated by the fact that in spite of the high value of platinum, the worth of the amount refined out of the ore shipments of 1913 was only $43,800, while the nickel was worth nearly $15,000,000 and the copper nearly $4,000,000. The percentage of platinum and palladium contained in a ton of the so-called "matte" produced by smelting the ore is only from 0.17 to 0.5 oz.[1]

In Manitoba, at the Pas, a shaft 40 ft. deep has been sunk by the Northern Manitoba Mining and Development Co., and a picked sample of material brought up showed $49 worth of gold and $17 worth of platinum. The presence of platinum here shows how widely diffused it is in this locality, for McCafferty's and the property of the Northern Manitoba Mining and Development Co., in each of which it has been found, are distant about 5 miles respectively from the site of the new discovery.[2]

Colombia.—In a paper read before the Second Pan-American congress in Washington, D. C., Jan. 3, 1916, Dr. Tulio Ospiña, director of the School of Mines at Medellin, Colombia, gave some valuable and interesting details regarding the platinum deposits of Colombia. He estimates the area of the alluvial deposits of gold and platinum at over 5000 square miles, the region lying west of the central ridge of the Colombian Andes, in the drainage basin of the Atrato and San Juan Rivers, and extending south of the latter to the Mira River, in the direction of the coast line. The stream beds in which platinum occurs are those in which the Tertiary conglomerates have become eroded, the deposits being reconcentrates of the older gravels. The Tertiary conglomerate is formed by rounded boulders of basic rocks, such as diabase, melaphyre, peridotite and dunite. A much larger proportion of platinum to gold is found in gravels of the San Juan River than in those of the Atrato, the two metals occurring in about equal quantity in the former, while in the latter the proportion is about 85 per cent. gold to 15 per cent. platinum. There are estimated to be 68,000,000 cu. yd. of gravel that can be regarded as certainly profitable for working; and there is a reserve total of 336,000,000 cu. yd. which may also prove productive. English and American capital control the most productive area. A dredge operated for a time in July, 1915, on the Condoto River by the Anglo-Colombian Development Co., appears to have shown good results. Other dredges are projected, and some

[1] *The Watchmaker, Jeweler, Silversmith and Optician*, Dec., 1916.
[2] *Can. Min. Jour.*, Nov. 15, 1916.

surveying has been done with a view to developing electric power. The U. S. Geological Survey has learned that there are indications of considerable areas of promising platinum deposits on the Atrato River, from its headwaters to a point well below Beta. Samples of gravels received by the Survey from the neighborhood of Quibdo, while showing considerably more gold than platinum, contain enough of the latter metal to merit interest.

In 1915 the greater part of the platinum output of the largest single producer in Colombia, the Anglo-Colombian Developing Co., affiliated with the Consolidated Gold Fields, Ltd., of South Africa, is believed to have been shipped to England, but the output of many independent producers continued to go to the United States.

In 1916 the crude platinum mined in Colombia, estimated at 25,000 oz., was refined in the United States, and reports received from domestic refiners show that 28,088 oz. of metals of the platinum group was recovered by them from all sources, foreign and domestic, of which 24,518 oz. was platinum. It is known that the Colombian deposits will be more extensively developed during 1917 than ever before, and it is estimated that at least 30,000 oz. of crude platinum, containing 85 per cent. metal, will be derived from that source.[1]

Colombia is an increasingly important source of supply, as shown by the accompanying table of imports.

UNITED STATES IMPORTS OF PLATINUM FROM COLOMBIA
(In troy ounces)

Year. (*a*)	Quantity.	Value.
1910	1,600	$31,383
1911	5,503	147,820
1912	6,627	219,128
1913	10,461	363,731
1914	12,387	398,657
1915	16,298	584,245
1916	24,774	1,677,805

(*a*) Fiscal year ending June 30.

Russia.—In order to present a more comprehensive and satisfactory view of the relations between platinum production, platinum exports and the home consumption of the metal in Russia, the Mining Department in Petrograd has summed up the statistics for a 25-year period, from 1889 to 1913 inclusive. The results are as follows:[2]

	Poods.	Kg.	Troy Oz.
Production	7837	128,378.44	4,127,367
Export	6428	105,297.52	3,385,265
Consumption	1409	23,080.92	742,052

It must be borne in mind that the official figures for the exportation

[1] U. S. Geol. Surv.
[2] Report issued in Petrograd, 1915, p. 78 (in Russian).

of platinum in recent years are considerably lower than the actual exports, since no small part was sent by post or taken out packed in luggage, and thus escaped registration. It has been hoped that the enforcement of a strict registration of the ore in the different localities where it is produced would furnish more complete and satisfactory statistics than have heretofore been obtainable.

PRODUCTION OF PLATINUM IN RUSSIA

Year.	Official.	Actual.	Year.	Official.	Actual.	Year.	Official.	Actual. (a)
	oz.	oz.		oz.	oz.		oz.	oz.
1899	191,464	380,900	1905	167,950	200,450	1911	187,008	280,000
1900	163,060	212,500	1906	185,546	210,318	1912	177,596	300,000
1901	203,257	315,200	1907	172,064	310,000	1913	157,735	275,000
1902	197,024	380,806	1908	156,792	250,000	1914	157,182	240,000
1903	192,976	226,000	1909	164,513	275,000	1915	119,789	124,000
1904	161,950	290,120	1910	176,334	300,000	1916	....	63,900

PRODUCTION OF PLATINUM IN THE URALS
(In troy ounces)

District.	1911.	1912.	1913.	1914.	1915.
South Verchotur	121,317	118,281	102,554	106,531	80,985
North Verchotur	11,367	13,061	11,376	7,426	12,288
Perm	46,882	38,706	36,880	38,051	22,996
Tcherdinsk	(a)6,400	6,166	6,109	4,753	3,518
South Ekaterinburg	(b)1,042	(c)1,382	816	421	(b)2
Total	187,008	177,596	157,735	157,182	119,789

(a) Estimated. (b) Includes 2 oz. from North Ekaterinburg. (c) 5 oz. from North Ekaterinburg.

The present writer, shortly after a visit to the platinum region in the Urals in 1891, reported that the "pay streak" in the Demidov mines was to be found at depths of from 6 to 40 ft., and had a thickness of from 6 to 10 ft. It rested directly upon a serpentine bed-rock. The material taken out during the winter was washed in the summer season, when the sluices were continually in operation. Each of the machines on the Demidov Estate could treat 400 metric tons of sand in the full day of 24 hr., yielding 2660 grams of metal. This would give 6.65 grams (0.214 oz.) per metric ton. The Report of the Russian Department of Mines for 1890 places the total amount of platinum sands washed at 773,153 metric tons, from which 2836 kg. of crude platinum was secured, or 3.67 grams (0.118 oz.) per metric ton. The Demidov properties were credited with 283,200 tons of the sands, furnishing 865.7 kg. of platinum, equivalent to 3.06 grams (0.0984 oz.) per metric ton.[1]

In 1913–1914 the average yield from the Ural placers had fallen as low as 0.05 oz., the gradual but steady decline being represented in the following figures:[2]

[1] Mineral Industry, 1, 379, (1892).
[2] E. de Hautpick, *Min. Jour.*, May 14, 1914.

1829–1838	0.50 oz. troy.
1838–1850	0.40 oz. troy.
1850–1883	0.33 oz. troy.
1883–1894	0.10 oz. troy.
1894–1907	0.09 oz. troy.

A new and promising source of platinum is promised as a result of experiments conducted in the platinum fields of the Nizhni-Tagilsk mining district by V. N. Chorzhevsky. He is trying to utilize the platiniferous qualities of the rock dunite, in which the presence of the metal appears to be connected with the existence of chrome iron ore. While scientists were already familiar with these facts, no attempt had yet been made to secure the metal from this source, and, if the present efforts prove successful, the immense reserves of dunite rocks which occupy an area of 11.7 square miles in the Nizhni-Tagilsk district alone, should furnish a much needed contribution to the world's stock of platinum. The method for extraction is to grind the rock under runners, collect the chromite slack, grind this in turn and then leach the pure metal from it. To test the prospects of success the chromite slack remaining after washing the platinum sands, being carefully cleared of all visible platinum, yielded after an experimental grinding by runners, over 6.220 grams (200 oz.) of metal from 9720 lb. of material. This was in March, at a time when it was still impossible to deliver dunites to the factory. The platinum yield of the gray slack, consisting mainly of undecomposed dunite secured from the dredges in washing for platinum, was 2.6 zolotniks (11 grams) from 3600 lb.[1]

Spain.—The platinum locality in the Rondo Mountains, a chain running parallel with the Mediterranean coast eastward from Gibraltar, is stated to be not far from the town of Rondo, which is situated 50 miles north-northwest of Gibraltar, 35 miles west-northwest of Malaga, and 60 miles southeast of Seville. The rock system is said to exhibit analogies with that of the Urals, indeed, according to Señor Don Domingo Orueta, of the Mapa Geologico, the chains are absolutely similar. Here platinum occurs in the dunite, the most basic rock of the central mass, consisting of olivine and chromite. In association with the latter the platinum is found, scattered through the mass, instead of being concentrated as in alluvial deposits. The platinum district has been taken under the authority of the Spanish Government, which has prohibited prospecting, and is proceeding to test the value of these deposits as well as their extent.

A royal decree published in the Gaceta de Madrid, the official organ of the Spanish Government, defines the area of the deposits of platinum, chromium, and nickel discovered by Señor Orueta and relinquished by him to the Government. Concessions to exploit the mines can be secured

[1] *Eng. Min. Jour.*, May 26, 1917; *Chem. Trade Jour.* and *Chem. Eng.*, Apr. 28, 1917.

from the Government by foreigners as well as by Spanish subjects, on making application to the Señor Ministro de Fomento, Madrid, Spain.[1]

The extent of the platinum deposits in the Serranía de Ronda, as determined by investigations conducted from January, 1915, to October of that year, and since February, 1916, has been announced by the Geological Institute of Spain in a volume issued this year.[2] The precise area of the deposits has not been accurately ascertained, but its great extent is indicated by the fact that it embraces 12 or 14 rivers, the beds of which contain platiniferous material, enough being present to furnish profitable working by dredges for many years. The deposits are loose peridotite sands which are found in the river beds at a depth of from 10 to 15 m. Up to June, 1916, some 3½ km. of the Rio Verde have been examined, this zone being chosen as presumably an average one. The platinum content here increased gradually from 0.08 gram per cu. m. of material at the lower end up to 0.2 gram per cu. m. at the highest point attained before the report. While these results are regarded as very encouraging, they of course need to be completed by the further investigations that will be carried out.[3]

Other Countries.—It is reported that every year a small quantity of platinum, never more than a few ounces, figures in the returns of the precious metals obtained by the Burma Gold Dredging Co. at Myitkyina. In 1915 the quantity secured was 17.7 oz., valued at £100.[4]

A small quantity of platinum, amounting to 56 oz. troy (1741.6 grams), was obtained in 1915 in New South Wales, Australia, from gold placer deposits on the northern beaches on Evans River, in the Fifield gold fields, and in the Parks district. In 1914 the quantity recovered was 244 oz. (7589.3 grams).

Platinum deposits, in association with alluvial gold and iridosmine, occur in Japan, in the Yûbari-garva, the Pêchan, and other rivers in the Hokkaido; with gold and iron sand it is found in Nishi-Mikawa, Province of Sado. In none of these localities has the mother rock been ascertained. A sample of minerals with specific gravity in excess of 5, collected in gold washing in the Hokkaido, appeared platinum iridosmine, cinnabar and magnetic iron in admixture with gold. Whether all these minerals were derived from the same parent rock was uncertain. The specific gravity of the iridosmine of the Pêchan in Esashi is 22.275, while that of platinum from Usotanni in the same mining district is 21.509, according to determinations made by the Chemical Laboratory of the Japanese Imperial Geological Survey. The quantity of platinum found is only

[1] *Comm. Rept.*, Dec. 14, 1916.
[2] *Memorias del Instituto Geológico de España*, Estudio Geológico y Petrográfico de la Serranía de Ronda, Madrid, 1917.
[3] *Comm. Rept.*, May 5, 1917.
[4] From the *Records*, Geol. Surv. of India, 47, part 3, 163 (1916).

2 or 3 per cent. of the amount of iridosmine discovered. The largest of the flattened grains weighs but 0.637 gram. That from Sado is in very minute grains. It is believed that more careful researches of the placer gold regions of Hokkaido may not improbably reveal richer platinum deposits.[1]

Metallurgy

The method of refining platinum employed in the United States Assay Office is described as follows:[2] In the electrolytic process of refining gold, platinum remains in solution in the gold chloride electrolyte, from which it is precipitated by means of ammonium chloride. The precipitate is then well washed and reduced at a red heat to a metallic platinum sponge. This naturally contains impurities, and is therefore redissolved in aqua regia, and evaporated almost to dryness, so as to expel the nitric acid, sulphur dioxide being then passed through it until all the gold is precipitated. Upon this it is oxidized to bring all the platinum into a platinic state and precipitated with pure ammonium chloride. The precipitate is then reduced in the usual way to metallic platinum sponge.

The ruling high price of platinum having naturally induced the composition of many more or less promising substitutes therefor, there is always a considerable risk that objects made of such substitutes, if at all resembling platinum in external appearance, will be palmed off as being of the genuine metal.

Uses

It is estimated that in the manufacture of the 1,500,000 lb. of contact mass used in recent years in the various plants in the United States employing the contact process for making concentrated sulphuric acid, for use in dehydrating nitric acid, approximately 1365 kg. (43,888 oz.) of platinum were to be found. The companies report losses of this material ranging from a trifling amount up to 0.25 grams per ton of acid. This very slight loss would entail but a small quantity of platinum for renewal purposes, and hence the notable demand that really now exists for the metal in this industry must be due to the construction of additional contact masses. Our participation in the war is expected to intensify the demand for this use during the present year.

One of the uses to which platinum is put that has a direct connection with the manufacture of the internal-combustion engines so indispensable in war time is for some of the delicate parts of the ignition system.

In the production of photographic paper platinum has been found valuable. For this purpose platinum solution is used, which is reducible

[1] Tsunashiro Wada, "Minerals of Japan," Eng. transl. by Takudzi Ogawa, Tôkyô, 1904, pp. 8, 9.
[2] From letter of Hon. Verne M. Bovie, Supt. of the U. S. Assay Office, at New York, to the writer, dated June 6, 1917.

to metallic platinum by light. The paper is coated with this, the operation being performed in darkness. After having been thoroughly dried out, sheets of it are made up in light-proof packages and disposed of to photographers. The advantage possessed by such paper is the superior stability of the photographic impression, which lasts much longer without fading and is not liable to deterioration from chance exposure to chemical fumes.

A circular letter issued by the Jewelers' Vigilance Committee contains the following statement regarding the use of platinum in jewelry: "Platinum is par excellence the metal for fine and delicate jewelry, firstly because its brilliant white color enables the jewelers to obtain beautiful effects in the setting of diamonds, both small and large, which can not generally be obtained with gold, on account of its color; secondly on account of its malleability, ductility, rigidity and tenacity, because of which the most delicate and intricate designs are possible, with a surprisingly small amount of metal; and lastly because jewelry made of platinum will retain stones in their settings without the heavy beading required in gold and will not tarnish or oxidize from exposure to air, fumes or acids, or when worn on the body. This combination of qualities does not exist in any other known precious metal and has made possible most of the great advance in the jewelry art of recent years."

The patriotic readiness of all interested in the jewelry industry to consider the national welfare is best shown by the resolutions adopted by the Committee. These resolutions pledge discontinuance of the manufacture and sale of bulky and heavy pieces of platinum jewelry and all non-essential platinum parts such as scarfpin stems, pin tongues, joints, catches, swivels, etc., where gold will satisfactorily serve, and strongly recommend this policy to all manufacturing and retail jewelers. This action was praised by Secretary Redfield, and the Committee points out that the Government has not requested stopping the use, sale, or purchase of platinum in jewelry.

Substitutes

Gold as a substitute for platinum is used in a new gold-iridium alloy marketed by a California firm under the name "Palau." As gold is now worth but one-fifth the price of platinum this new alloy can be sold much cheaper than the platinum-iridium alloy so long in use. According to a test made of crucibles by the Bureau of Standards, the loss in weight by heating to 1200° C., while greater than that suffered by platinum crucibles with 2.4 per cent. iridium, was less than when but 0.6 per cent. of iridium was used. The melting point, 1370° C., corresponds to that of an alloy of 80 per cent. gold and 20 per cent. palladium. A comparison of the effect produced by different reagents upon "Palau" and upon ordinary platinum gave quite satisfactory results for the former. One exception, however, was alkali pyrosulphate, to which the alloy proved much more sensitive than does platinum. On the whole objects for laboratory use made of "Palau" promise to be satisfactory substitutes for those made of platinum.[1]

Among the several proposed substitutes for platinum, "rhotanium," a name given to alloys containing from 60 to 90 per cent. of gold with palladium, is pronounced to be unsuitable for use with hot concentrated nitric acid, or for electrolytic anodes; for all other chemical purposes it has been found entirely satisfactory provided it is properly composed and manufactured. Experiment has shown that it loses less by volatilization at temperatures lower than 1300° C. than does commercial platinum. It is both malleable and ductile, and can be welded by the employment of a flux or other reagent. The specific gravity varies according to the composition, ranging from 16 to 18.5. This composition makes a good substitute for platinum in the following uses:

In electric heating units, within the limits indicated by its temperature. The qualities of high resistance and a low temperature coefficient recommend it especially in this connection.

For contact terminals in a number of forms of automatic electric devices such as are employed in certain types of telephone switchboards, signal devices, and lighting and ignition systems, indeed in most cases except those where a high percentage of iridium alloyed with platinum is needed.

The rhotanium alloy successfully withstood the tests regarding its adaptability for certain magnetos; however, experiments in the case of a magneto for a high-grade aeroplane-engine gave only negative results.

For jewelry, platinum is said to be surpassed by "rhotanium," as it is harder and can thus be given a finer finish. However, while it has practically the color of platinum, it is just as little subject to tarnishing or corrosion, and can be just as easily worked.[2]

An alloy of nickel, chrome, tungsten, etc., that has been patented and is marketed under the name "Amaloy" has been found suitable by railway signal manufacturers for relay contacts, where the voltage is comparatively low. Another use is for orthodental work, and for the metal anchor used to attach an artificial tooth to the natural root. This metal compound proves highly resistant to corrosion, cold nitric and sulphuric acids, which seem to have no effect upon it; it does not corrode in the atmosphere. Hence a blade formed of it would keep its edge in-

[1] *Comm. Rept.*, May 2, 1917.
[2] *Jour. Ind. Eng. Chem.*, June, 1917.

definitely without corrosion, a most important consideration in the case of surgical instruments. The melting point is 2400° F. (1315° C.) and the substance possesses great tensile strength.[1]

For contact points in various types of ignition systems, magnetos, spark coils, etc., for automobiles, tungsten has been substituted.

The leading-in wires of incandescent lamps have been satisfactorily made of a copper-alloy in which no platinum enters.

Targets for X-ray tubes are now almost always made of tungsten instead of platinum. A large block of tungsten constitutes the cathode of the Coolidge tube, and in other types of tube a tungsten dish in copper is employed. Practically no platinum is now used in the targets of X-ray tubes, but it is still used to some extent in the seals of the tubes.

For dental work, in which platinum was much favored in the past, a gold-coated tungsten wire has been successfully substituted for one of platinum and gold.

The substitution of tungsten instead of platinum for non-magnetic watch springs has been suggested.

[1] Communicated by Dr. F. C. Runyon, in letter dated June 11, 1917.

POTASSIUM SALTS

J. W. Beckman

The potash situation all over the world did not change materially in the second year of the great war. Due to the complete blockade of Germany, there does not seem to have been any tonnage of potash shipped from that source, excepting possibly a very small amount to the neutral countries, Sweden, Norway, Denmark, and Holland.

A vigorous search for potash all over the crust of the earth has been continued, and sources of potash not heard of before at various points of the world have been discovered.

Great Britain.—A small amount of potash was imported to Great Britain and also small amounts of potash were exported from British India. The imports into Great Britain and the exports from British India were all nitrates of potash.

Spain.—The Spanish Government had reserved to itself the right of exploration of the potash deposits of the Provinces of Barcelonia and Nirida. This reservation was made for 2 years and expired on Oct. 1, 1916. A Royal Order published on Sept. 28, 1916 extended the reservation in favor of the State for another 2 years. In connection with the publication of this order, the government notes that it has not yet been able to undertake work on these potash lands owing to the lack of sufficient appropriations. A Royal Order authorizes the Geological Institute of Spain to draw up an estimate of the expenses likely to be incurred in the investigation of these deposits.

Russia.—Reports from Petrogràd show promising results from searches for potash in Asia. One of the results of the search was the finding of potash in Fergana in Central Asia. It is said that only very recently, but without the appearance of doubt, success has been obtained in the search for potash salts which have been clearly discovered in the place marls, limestone, and sandstone of the so-called Fergana geological bed, which belongs to the Eocene and is said to contain colossal reserves of potash salts. The beds of the Fergana formation have all been known to contain saltpeter to the extent of 2 to 5 per cent.; and as these beds are extensive over the whole district, the quantity of potash that it may yield to enterprise may be placed at millions of tons. The conditions in which the deposits of saltpeter are found in the Fergana beds are stated further to be remarkably favorable for the production of potash; if for no other reason than that the district, besides holding this important product, is also rich in fuel, namely, coal; and to this must be added, of course, the well-known petroleum reserves of the Fergana district, which have been operated for many years now and in which the Nobel house is reputed to be intimately interested. Under these conditions with a great strata containing saltpeter in sufficient percentage in proximity, of cheap fuel, as well as plenty of water, available, the exploration of the saltpeter deposits of the Fergana beds could be undertaken with a certain prospect, not only of being able to supply the Russian War Department, but supplying the much needed fertilizers of the Russian farmers. Sampling and analyses of these beds have been made and they show 2 to 5 per cent. of potash. The potash-bearing mineral does not lie on the surface; and it is found that the distribution of potash does not diminish in depth. The results so far obtained have been sufficiently reassuring that parties have already given much attention to these deposits. It has also been suggested in Russia that deposits of potash, so anxiously looked for, should be found in conjunction with the salt beds that are developed in Central Asia, as well as Siberia.

Japan.—The Japanese potassium chlorate production has shown a most remarkable increase. They used to produce 300 tons per annum and now produce close to 4000 tons per annum. The raw material for this salt was undoubtedly obtained from some local sources, such as bittern obtained in the solar evaporation of seawater.

PRODUCTION OF POTASSIUM SALTS IN GERMANY. (*a*)
(In metric tons and dollars; 1 mark = $0.238)

Year.	Kainit.		Potassium Salts Other than Kainit		Potassium Chloride.		Potassium Sulphate.		Potassium Magnesium Sulphate.	
	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.
		$		$		$		$		$
1898	1,103,643	3,835,856	1,105,212	3,576,628	191,347	6,380,220	18,853	763,397	13,982	259,485
1899	1,108,159	3,838,250	1,384,972	4,202,000	207,506	6,801,250	26,103	1,027,500	9,765	195,000
1900	1,178,527	4,134,000	1,874,346	5,643,750	271.512	8,793,750	33,853	1,249,250	15,368	280,500
1901	1,500,748	4,327,250	2,036,326	5,443,250	282,750	8,782,250	27,304	1,460,000	15,612	286,500
1902	1,322,633	4,571,980	1,962,384	4,949,448	267,512	7,507,710	28,279	1,079,092	18,147	334,390
1903	1,557,243	5,208,154	2,073,720	4,993,478	280,248	8,125,320	36,674	1,389,444	23,631	441,252
1904	1,905,893	6,322,470	2,179,471	5,305,972	279,238	8,425,676	43,959	1,664,572	29,285	545,972
1905	2,387,643	7,976,808	2,655,845	6,396,250	373,177	10,580,528	47,994	1,804,040	34,222	614,754
1906	2,720,594	8,918,574	2,821,073	6,538,336	403,387	11,034,632	54,490	2,032,520	35,211	644,028
1907	2,624,412	8,579,206	3,124,955	7,314,930	473,138	12,639,704	60,292	2,216,494	33,368	631,652
1908	2,715,487	9,196,082	3,383,535	7,720,006	511,258	13,369,174	55,756	2,037,518	33,149	663,068
1909	3,181,349	10,646,792	3,860,685	8,787,198	624,994	16,245,642	68,539	2,574,684	38,722	697,816
1910	4,249,667	12,712,056	4,062,004	9,034,004	741,259	17,371,144	84,583	2,989,756	37,439	668,066
1911	4,425,497	13,757,452	5,181,379	11,794,328	838,420	19,851,342	107,631	3,967,460	42,253	780,974
1912	5,889,238	18,178,916	5,271,964	10,294,214	506,744	16,336,792	123,407	4,848,714	54,435	(*b*)
1913	....	....	....	....	....	....	....	....	......	......

(*a*) From *Vierteljahrshefte zur Statistik des Deutschen Reichs.* (*b*) Value, $1,052,912.

Exports from Germany during 1912 and 1913 are given as follows:

Articles.	1912.		1913.	
	Metric Tons.	Value.	Metric Tons.	Value.
Carnallite with at least 9 per cent. and less than 12 per cent. K_2O.	6,853	$46,000	520	$3,000
Raw salts with 12 to 15 per cent. K_2O..............	853,117	4,094,000	1,124,816	6,697,000
Salts with more than 15 to 19.9 per cent. K_2O.......	35,530	286,000	49,687	404,000
Fertilizer salts, including potash fertilizer, with 38 per cent. K_2O.	373,685	5,510,000	460,865	7,855,000
Chloride of potash, not in shells or capsules..........	1,068	158,000	1,164	166,000
Sulphate of potash..............................	85,749	3,660,000	133,358	5,700,000
Sulphate of potash-magnesia.......................	48,600	1,085,000	59,207	1,339,000

[1] *Amer. Fert.*, Mar. 18, 1916, p. 31.

Potash in the United States

The acute condition of the potash situation in the United States is apparent when it is realized that the daily production from kelp, cement, alunite, feldspar, and from natural deposits is placed at 45 tons of K_2O. A production of 45 tons daily would be 6 per cent. of the daily consumption before the war of 745 tons of K_2O. Of the 45 tons daily produced in the United States now, it is estimated that the Nebraska Lakes furnish at least one-half, if not more.

IMPORTS OF POTASSIUM SALTS (*a*)
(Tons of 2000 lb.)

	1912.		1913.		1914.		1915.		1916.	
	Quantity.	Value.	Quantity.	Valuc.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.
Bicarbonate (crude)....	....	....	....	....	....	....	2,038	$83,502	770	$53,752
Bicarbonate (refined)...	138	$13,155	156	$14,295	239	$22,767	192	20,341	60	22,596
Carbonate (crude)....	3,299	207,417	5,032	295,066	4,523	240,451	4,310	291,341	222	27,689
Carbonate (refined) ..	5,313	383,958	7,018	412,587	5,211	368,858	1,189	92,959	87	38,604
Chloride....	242,033	7,235,728	223,837	6,737,757	263,039	7,925,781	102,882	3,660,353	2,126	466,888
Chlorate....	21	3,444	618	66,609	20	3,408	14	4,614	....	....
Chromate...	22	2,273	14	2,601	17	2,822	20	3,317	1	391
Cyanide....	1,048	312,777	475	137,535	618	183,259	474	143,331	27	9,311
Hydrate....	4,250.	338,780	4,553	360,419	4,292	338,627	2,497	225,002	20	9,222
Kainit......	479,817	2,400,590	466,184	2,149,689	589,245	2,579,619	79,124	444,996	64	1,795
Nitrate (crude)....	3,086	213,258	5,495	288,995	1,764	115,470	339	22,483	2,706	734,123
Nitrate (refined)...	221	23,896	197	2,2142	182	20,173	34	4,222	2	749
Prussiate (red)......	35	11,264	33	11,302	45	15,325	42	14,922	1	3,182
Prussiate (yellow)...	1,036	203,295	1,406	309,309	1,754	390,021	1,158	255,711	22	31,651
Sulphate....	50,551	1,853,236	48,023	1,798,362	50,384	1,887,491	21,705	1,071,623	2,427	197.808

(*a*) For the fiscal years ending June 30.

There are three sources of potash which seem to promise well for the future. These are potash-bearing solutions, potash-bearing mineral wastes, and sea kelp.

Potash-bearing Solutions.—The potash-bearing solutions are to be found in many of the Western States of the United States. The so far most promising potash-bearing lakes are those located in Nebraska, among them Jesse Lake. The potash obtained from this lake is practically free from chlorine and is obtained by evaporating the waters of the lake. The average content of soluble K_2O from these waters is 28 per cent. The potash present in these lakes is supposed to be an accumulation of years of waters laden with potash leached from the ashes of repeated prairie fires.

The Searles Lake deposit in the southern part of the State of California has been worked to a limited extent and new equipment has been installed.

A refining plant at San Pedro, Cal., has been erected, where the final treatment of the various salts obtained from these saline brines will be accomplished.

Owens Lake, situated in a very similar manner to Searles Lake, in California, contains potash and bicarbonate of soda. In recovering the bicarbonate of soda, the potash is recovered and contributes to a limited degree to the available potash resources of the United States.

In connection with some salt refineries on San Francisco Bay, potash is recovered from the bittern, after the salt is removed from the seawater. This waste liquor, which represents the concentrate of the various other ingredients, contains magnesium chloride, as well as potassium chloride. The Diamond Match Co. and some other companies are recovering potash from the Great Salt Lake in Utah.

Kelp.—Along the Pacific Coast at various points, small and large plants have been erected for the purpose of recovering the potash and other valuable ingredients present in the sea kelp growing in large fields along this coast. The most noted plant for the recovery of these materials is that built by the Hercules Powder Co. close to San Diego. It is reported that they are planning to recover 40 tons of potash per day in addition to large quantities of acetic acid obtained by fermenting the sea weed. The Diamond Match Co., Swift & Co., and many others have established plants for the recovery of potash. The United States Agricultural Department is planning to establish an experimental plant, for the purpose of studying the best method of recovering potash from the Pacific Coast sea kelp, at Summerland on the coast of Santa Barbara County. There has been some agitation in the State of California over the regulation of the harvesting of the sea kelp. Some care has to be taken to prevent the demolishing of this source of potash by careless and wasteful harvesting.

The recovery of potash from the kelp is accomplished in various ways. In some cases the kelp is just dried, by which a fertilizer is obtained, containing some nitrogen and potash. In other cases the potash is leached from the kelp and, again, the potash is obtained from the kelp ash after the kelp has been burnt.

Potash-bearing Mineral Wastes.—It is becoming more and more apparent that the potash-bearing mineral wastes of many of the large industries of the United States provide sources for potash which are of enormous magnitude. A number of cement mills have been supplied with suitable means for recovering the potash previously gone to waste in the dust of these mills. The Cottrell electrical precipitation method is perhaps the most common one, while dust settlers and washing chambers have been installed at other mills, all yielding potash as a by-product from the kilns burning the cement clinkers. Even the blast-furnace operations of the United States, with accompanying dust, have been carefully investigated and it has been found that large quantities of potash could be recovered from the iron industry, if suitable equipment were installed.

Alunite.—Alunite deposits at Marysvale, Utah, have continued to be operated and new companies have been organized to produce potash from this source.

Other Sources of Potash.—A great number of possibly available sources of potash have been put to test. Among these are ashes of hard wood and soft wood, as well as ashes from sage brush.

The potash situation in the United States is most acute, but indications are that the careful study of means to overcome the present waste of potash, in industries using raw materials with a small potash content and already established, promises well for the future. Potash may eventually be recovered from these industries in sufficient quantity to make the United States practically independent from foreign sources of potash.

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PRECIOUS STONES

By George F. Kunz

The precious-stone imports for the calendar year 1916 total $51,117,-767, the largest annual importation ever recorded. It should always be borne in mind that the import valuations are much below the actual final cost to the importers, as they take no account of duty, freight, insurance, etc. For such charges it is estimated that 26 per cent. must be added to the invoice price; this would give $64,408,386 for the 1916 imports. Dealer's profits and incidental expenses would probably double the cost of the stones as purchased by the public, so that the final, or selling price of the precious stones, including settings, now so often of platinum, brought here in this one year would be about $130,000,000.

The invincible tendency of the precious-stone market to react against all unfavorable circumstances is shown by a comparison of two 5-year periods, that from 1908 to 1912, and that from 1912 to 1916 (1912 being included in both). The first of these periods gave the highest figures for any quinquennial period up to that time, $184,303,374, and yet despite the serious setback of 1914, when imports declined to less than $20,000,-000, the 5 years 1912–1916 represent another advance to a new record figure, namely $186,517,412. In the 25 years from 1893 to 1916, inclusive, precious stones worth $663,163,477 were imported. This figure with 26 per cent. added would give a final cost to the dealers of $835,000,-000, making a selling value of $1,670,000,000, if computed in the same way as the figures for 1916.

IMPORTS OF DIAMOND AND OTHER PRECIOUS STONES INTO THE UNITED STATES 1913–1916

	1913.	1914.	1915.	1916.
Diamonds, uncut, free	$11,616,286	....	....	$368,211
Diamonds, uncut, dut	956,576	$2,976,227	$7,047,945	11,264,704
Diamonds, cut but not set, dut	24,886,133	12,022,146	13,140,548	24,276,882
Bort, dut	....	....	26,752	62,901
Pearls and parts of, not strung or set, dut	5,004,489	2,142,221	4,309,837	11,972,018
Other precious stones, uncut, free	47,716	....	....	....
Other precious stones, uncut, dut	9,459	32,596	76,371	194,804
Other precious and semi-precious stones, cut, but not set, dut	2,740,804	1,630,715	1,021,221	2,143,543
Imitation precious stones, dut	1,299,145	961,082	898,656	834,704
Totals	$46,560,608	$19,764,987	$26,521,330	$51,117,767

The increase in the precious-stone importations for 1916, bringing the total up to the highest figure ever recorded for a single calendar year, was due to the exceptionally great value of the pearls brought here. This reached about $12,000,000, while in former years the five-million mark was only twice exceeded, in 1912 and 1913. Since 1900 it is estimated that pearls to the value of over $40,000,000 have been imported.

As a demonstration of the essential stability of the precious-stone market in the United States despite the greatest fluctuations, the following figures covering the calendar years of the two quinquennial periods 1907–1911 and 1912–1916 are too significant to require comment:

Imports of precious stones and pearls, 1907–1911.	
1907	$31,866,599
1908	13,700,404
1909	43,570,556
1910	42,315,830
1911	42,163,864
Total	$173,617,253
Imports of precious stones and pearls, 1912–1916.	
1912	$42,552,720
1913	46,560,608
1914	19,764,987
1915	26,521,330
1916	51,117,767
	$186,517,412

The former of these periods includes the financial crisis of 1907–1908, and the latter shows the temporary effect of the first years of the great war.

The total imports of precious stones, pearls and imitation stones into the United States from 1867 to 1916, inclusive, were as follows:

Diamonds and other precious stones	$736,703,696
Pearls	50,541,170
Imitation stones	5,796,314
Total	$793,041,180

In many of the earlier years no distinction was made between diamonds and other precious stones, but it is safe to estimate the value of the diamonds at from $680,000,000 to $700,000,000. In a very few years pearls were not separately entered, but this would not greatly change the total for these gems. The figures for imitation and artificial stones cover only the period 1911–1916, before which time not many were imported and they were not separately listed.

Diamond Trade Conditions

Since the early part of 1917, the diamond trade has been almost brought to a standstill by the activity of the German submarines and the consequent rise in insurance rates. On shipments from South Africa to London the rate on Mar. 9, 1917, was 5 per cent., and from London to the United States another 5 per cent. was charged, this rate having since risen to 8 per cent. These high rates would in themselves be discouraging enough, but could be offset by raising the price of the diamonds. When, however, a valuable shipment is lost, the insurance collected scarcely covers the cost of the stones and the premium paid becomes a dead loss to the importer, as he no longer has any chance to recoup himself from his profits. Still the active financial market that is promised will redound to the advantage of some, and should benefit trade in general and consequently the business interests of precious-stone dealers and jewelers. An indication of the confidence felt in the future by the London market is the fact that the Diamond Syndicate has recently purchased the Southwest Africa diamonds from the South African Union Government, thus centralizing the holdings of diamonds. This step should certainly preclude any decline in prices.

At the beginning of this year another increase of about 5 per cent. in the price of rough diamonds was made by the Diamond Syndicate. In Amsterdam rough material has been so scarce that the manufacturers have had but little to dispose of, since they wished to keep what they had for use in their own cutting establishments to furnish work for the cutters.

The British royal proclamation of Nov. 23, 1916, puts "diamonds suitable for industrial purposes" on the list of absolute contraband. "Emery, corundum, carborundum, and all other abrasive materials, whether natural or artificial," are placed in the same category.[1] The extensive use of the diamond drill in engineering operations, as well as the use of carborundum and of corundum for such purposes, explains the special restriction placed upon these materials.

The stability of the gem market in London was tested at the beginning of this year by the forced sale of a London firm, by order of the Board of Trade, under the provisions of the Trading with the Enemy Act. The pearls brought high prices, as might be expected from the present scant supply. A single necklace of exceptionally well-matched pearls sold for £25,600 (about $125,000 at normal exchange). The first 3 days of the sale realized £100,000. Last December the African Union invited tenders for 31,000 carats of diamonds, so that the former German source of supply is about to be utilized again, at least to a limited extent.

In the early part of last year an import duty of 7½ per cent. was imposed by the Indian Government upon unset precious stones and pearls imported into that country. Pearls were, however, exempted from the provision on Mar. 26, 1916, and on Sept. 2 an exemption was also accorded to importers of uncut precious stones. As to the cut stones, no change was believed to be desirable, since in case of reëxportation, arrangements had already been made for the payment of a drawback by the principal Custom Houses. These exemptions had been strongly urged by a Com-

[1] *Min. Jour.*, Nov. 25, 1916.

mittee of the Bengal Chamber of Commerce, because of the fact that, in their opinion, so heavy an impost as 7½ per cent. would work serious injury to the Indian jewelry trade.[1]

In order to relieve in some measure the pressure brought to bear upon the jewelry trade in France, the Minister of Commerce issued on Oct. 12, 1916, a notice permitting, with special authorization, the importation of diamonds and precious stones, if cut for jewelry manufacture, up to the value of the exports of similar goods. These exports need not, however, have been made by the individual or firm receiving the imports, the evident object being to avoid any financial drain upon the country, while favoring the success of the special industry, as the money sent out to pay for the imports would be offset by that received for the exports.

Precious stones to be utilized directly for jewelry can only enter Italy by special permission of the Minister of Finance, but those in uncut state which are to be worked up in Italy for use in watch-making may now be passed through the Italian Customs, although before the latter part of 1916 even these were not admitted.

The difficulties experienced by the Germans in disposing of some of the jewel-heirlooms that the exigencies of the war have made it necessary to sell, received a curious illustration recently, when two men were tried and sentenced for endeavoring to smuggle some diamond jewelry into the port of New York. In the ordinary course of things the smuggled jewelry would have been confiscated by our Government, but as it was proven that the men were only acting as special messengers, there being no other way of sending German jewels to this country, the Custom House officers accepted the explanation that the failure to declare the goods on arrival was due either to negligence, or perhaps to a design of selling the gems for the smugglers' own benefit. In any case, this serves to show how effective have been the measures taken by the rulers of the sea.

The Diamond Industry in Holland and Belgium

There have been no regular imports of diamonds from Belgium to Holland for a year or more, although a few may have been smuggled across the frontier. In the early part of the war some diamonds must have been brought in from Belgium, as they were to be had at that time in Amsterdam. Of the Belgian diamond-cutters it is estimated that about 800 have come to the Netherlands, but among these are many born in the latter country, who returned to their native land because they could not find work to do in Belgium.[2]

[1] *The Watchmaker, Jeweler, Silversmith and Optician*, Nov. 10, 1916.
[2] Communicated by Consul Frank W. Mahin of Amsterdam, in letter dated May 8, 1917.

As a result of the German occupation of Antwerp, and the consequent departure from that former diamond center of most of the Belgian diamond-cutters, this industry has received a powerful impetus in England. While quite a number of diamond factories have been started in London with Belgian workers, Birmingham, probably the leader in the British jewelry trade, has also come into prominence in the diamond-cutting art. An establishment started there has proved a great success, and toward the end of 1916 there were 80 skilled Belgian operators employed, while a number of British boys were being passed through an apprenticeship. It is said that many of the latter have shown marked aptitude for the work. Although it is expected that most of the Belgian diamond-cutters now in England will return to their native land at the establishment of peace, the industry will have secured too firm a footing on British soil to be removed.[1]

The attempt to start a diamond market at Scheveningen, Holland, by Belgian diamond merchants, though promising at the outset, was doomed to failure, as it induced the Union of Dutch diamond dealers in Amsterdam to discourage the new competition. Within a year's time the Amsterdam dealers had secured control of the new market, so that now the Belgians who desire to sell their diamonds in the United States must do this by way of Amsterdam. During its short-lived existence, diamonds to the value of $1,837,204 were exported to the United States from Scheveningen, as follows: 1914, rough, $16,349; cut, $237,088; 1915, rough, $25,568; cut, $1,558,199.

To what a great extent Amsterdam has profited by the suppression, or at least the great curtailment of the diamond industry of Antwerp, its successful rival of late years, is shown by the value of the diamond exports invoiced at the American consulate in Amsterdam during the first 3 months of 1916. The amount exceeded that for any preceding first quarter of a year, as appears from the following comparisons for 1911 to 1916:[2]

1911	$2,620,074
1912	2,046,202
1913	3,579,081
1914	1,935,620
1915	1,202,003
1916	5,154,990

In 1916 cut diamonds valued at $20,959,051 and rough stones worth $185,384, in all a value of $21,144,435, were exported from Amsterdam to the United States, as declared upon the invoices produced at the United States Consulate. In addition to this, a few stones went from the Rotterdam district. Exports of diamonds to all other countries outside of the

[1] Consul Samuel M. Taylor, of Birmingham, *Comm. Rept.*
[2] Consul Frank W. Mahin, of Amsterdam, *Comm. Rept.*, Apr. 29, 1916.

United States in 1916 are estimated to have been worth from $2,000,000 to $3,000,000.[1] The restrictions on the export and import of diamonds and the high rate of insurance from Holland to American and other ports have operated to curtail the trade in diamonds.

The number of unemployed workmen in the Amsterdam diamond industry at the beginning of 1915 was 8143; in the middle of the year, 6170; at the end of the year, 3752. As the total number of workers is about 9500, some 40 per cent. were still unemployed at the end of 1915, in spite of the notable revival of the diamond industry due to demand from the United States.[2]

The Amsterdam diamond market in May, 1917, showed improvement over the conditions ruling during the preceding month, and as exports were easier to make there was better employment for the diamond workers. Still, the fact that as many as 5000 are unemployed at present signifies how far conditions are removed from the normal. The larger sizes of diamonds find a strong market, and the advance in price has been notable in those weighing from ½ carat down. Light cape stones of the finer hues are exceedingly scarce and in some demand. The difficulty in obtaining diamonds of a required quality is a handicap to jewelers, as well as the increasing prices, so that in London dealers may often be seen at the weekly auction sales of well-known firms. There is an equal scarcity of fine gems in the pearl trade. In the Paris market prices have risen steadily owing to the curtailment of the export of pearls from India. An increased demand in London for rose-cut diamonds is expected to result from the introduction of jeweled brooches and badges with regimental colors, the manufacture of which has constituted a good share of the business recently done by West End manufacturers.

An intelligent adaptation of the needs of an industry to the stern requirements of war time is reported from Amsterdam, where the shortage of coal had forced the Dutch Government to prescribe a reduction of 25 per cent. of the normal consumption at factories. To avoid the injury to the diamond-cutting industry that might result from this, a committee of the trade has made arrangements to concentrate all the diamond factories into a single organization, and shut down 80 of the smaller factories, while carrying out the work in 22 of the larger ones. Due compensation for eventual losses is to be accorded to the proprietors of the establishments that have been closed.

Government Regulations

The forms of the diamond guarantees required by the British Government before according the privilege of importing diamonds into the

[1] Communicated by Consul Frank W. Mahin, of Amsterdam, in letter dated May 8, 1917.
[2] *Suppl. Comm. Rept.*, July 20, 1916.

United States have recently been modified to some extent. Especially is this the case with the guarantee given by the importer of industrial diamonds as will appear by comparing the following briefer form with that published in the last report:[1]

DIAMOND GUARANTEE

HIS BRITANNIC MAJESTY'S CONSUL GENERAL,

NEW YORK.

Shipper........................	In consideration of your consenting to the delivery to us of the industrial diamonds specified in the margin, we
Sender........................ From........................	hereby give you the following undertaking which shall remain in force so long as Great Britain continues at war with any European Power:
Marks........................ Weight........................	That the diamonds if released will only be sold or disposed of by us for industrial purposes in the United States, and will not be exported, or sold for export, directly or indirectly, to any country at war with Great Britain.
Parcels........................	We further undertake not to dispose or sell the diamonds now released or any other industrial diamonds which may now or hereafter be in our possession to any person in the United States other than legitimate American users of such diamonds, whose guarantee to your satisfaction against the re-exportation or re-sale of the same we will produce to you within seven days from the date of sale.
	We further agree that all industrial diamonds that are sold to persons outside the City of New York shall be handed in unsealed packages to Mr. R. C. Munro of 452 5th Avenue, New York City, who will be at his office for one hour each week day to receive the same. The packages must be sealed in Mr. Munro's office and sent to their destination by registered mail, Mr. Munro undertaking to deliver to us the official post office receipts.
	We further undertake to produce on demand, for the confidential inspection of the British Consul General, the firm's sales records or other documents showing the disposal of the diamonds above referred to.
	We further undertake in the event of our importing any diamonds from Holland, or other countries than Great Britain, that we will have the same consigned to the British Consul General at New York to be released under similar conditions.

Here, as will be noted, the importer binds himself not to sell the diamonds delivered "to any person, co-partnership or corporation in the United States or elsewhere," and also engages not to make any transfer of diamonds "now or hereafter" in his possession to any country with which Great Britain is at war "or to any person or firm with whom British subjects are prohibited from trading."

Many gem dealers favor the enactment of a Federal law to control the trade in artificial precious stones and imitations, the legislation

[1] MINERAL INDUSTRY, **24**, 594–595.

to be on the lines of the pure-food laws, and to provide for an expert examination of the stones when treated as interstate commerce. As things are now, a purchaser is exclusively dependent upon the word of the firm he trades with, there being no effective legal remedy for misrepresentations in regard to the genuineness of the precious stones that are sold. In France, where the most successful imitations, or "reconstructions," have been made by means of synthetic processes, the laws are very stringent in this matter, and the jeweler or gem dealer who fails to properly designate the true character of the gems he sells is liable to be forced to pay a heavy penalty for his negligence, intentional or unintentional.

The Treasury Department has ruled that unset diamonds and other precious stones sent to this country "to have blurs polished therefrom, or to have defects removed by recutting or repolishing or similar work in the nature of repairs which does not destroy their identity," can be accorded free entry under bond. As, however, the certain identification of such stones offers considerable difficulty, the port collectors are required to satisfy themselves as far as may be of the bona fides of each importation. Full details as to weight, size and color, and as to any characteristic peculiarities must be furnished when the stones are received, and before allowing them to pass out again the appraiser must examine them as to their identity. The exportation must be made from the same port at which the stones entered.

A notice was received from the office of the Second Assistant Postmaster General, Oct. 3, 1916, to the effect that sealed or unsealed, registered or unregistered, packages of precious stones would be received in the regular mails from foreign countries. The acceptance of such matter for mailing, was, however, subject to determination by the country in which it was offered, but when received in the United States, in the regular mails, the packages were to be subject "to all customs regulations," in the same manner as though imported by parcel post, freight or express. The packages must be plainly marked abroad with the words "Dutiable" and "Subject to examination by United States Customs Officers," and they may also be marked "Precious Stones." Each package must contain an invoice giving an accurate statement of the value of its contents.[1]

Precious Stones of Madagascar

In Madagascar only 224 lb. of precious and semi-precious stones were produced in 1915, against 2834 lb. in 1914. The data for 1915 show in that year 95 lb. of garnet and other stones for industrial purposes and 129

[1] Communicated in letter dated Oct. 18, 1916, from F. M. Halsten, Chief, Division of Customs.

lb. of gem-stones, beryls, tourmalines, spessartite (garnets), opals, topazes, amethysts, etc. There has been considerable demand in the United States during recent years for the gems of this great island, several kilograms of beryls having been brought thence to our country in 1915.[1]

Diamonds

South Africa.—The total value of all the diamonds found in the territory of the Union of South Africa, from the earliest date of existing records down to Dec. 31, 1915, is stated in an official report as follows:[2]

Province.	Value. Pounds Sterling.	Value. Dollars.
Transvaal	£18,392,609	$89,385,164
Cape	138,024,967	670,801,340
Orange Free State	13,325,702	64,762,912
	£169,742,678	$824,949,416

In 1916 the total production of diamonds in the Union of South Africa was as follows in the different diamond-producing States:

	Carats.	Value.
Transvaal	615,209	£933,643
Cape Colony	1,510,756	4,057,928
Orange Free State	220,365	736,820
	2,346,330	£5,728,391
Totals for 1912	5,071,882	£10,061,489
Totals for 1913	5,163,547	£11,389,807

This shows a return in some slight measure to normal conditions, the prices being relatively higher than before the war. Figured at £1 = $4.865, the value for 1916 would be $27,868,623, or $11.88 per carat. For 1912 the value would be $48,949,144, or $9.65 per carat, and for 1913 we would have $55,411,411 as the value of the total product, making a price of $10.73 per carat, more than a dollar less than in 1916.

The export tax on diamonds passed by the Parliament of the Union of South Africa is graduated in accordance with the average percentage of profit realized by each exporting company during the 3 years preceding Aug. 4, 1914. Should the percentage of profit not exceed 35 per cent. no export tax is imposed, but when it is greater an export duty of ½ per cent. is levied for every ¾ per cent. of profit until the profit reaches 42½ per cent., when the maximum duty, 5 per cent., is imposed. At the last annual meeting of the shareholders of the Jagersfontein Co., Chairman

[1] Consul James G. Carter of Tamatvae, *Suppl. Comm. Rept.*, Dec. 15, 1916.
[2] Union of South Africa, Department of Mines and Industries. *Annual Report of the Government Mining Engineer*, Pretoria, 1916.

Harris announced that no duty could be charged against this company, as the average profits during the 3 years mentioned were only 32.94 per cent.

The refusal of the British Government to allow the mining companies to secure dynamite under what is known as "Report A," which allows as much as may be required, has contributed to check operations to a considerable extent, so that the mines toward the end of 1916 were only producing about 27 per cent. of the average output. Of course, the intentional limitation of the mining on the part of some of the companies is another important cause of lessened production.

The pooling of all the South African diamonds recently arranged by S. B. Joel, and the arrangement by which the product of the Premier mine is in future to be sold by the London Diamond Syndicate, give a firm basis to the policy of coöperation that was initiated some time since between the two great diamond companies of South Africa.

The alluvial diggings of the southwestern Transvaal produced more diamonds in 1916 than in 1915, the value of the stones showing a larger increase than the number of carats found, as appears from the following table giving the returns for 1911–1916, as well as the value per carat in each year, in United States currency at $4.865 = £1.

Year.	Carats.	Value.	Value per Carat.
1911	37,861	$967,327	$25.55
1912	79,079	1,881,140	23.79
1913	81,943	2,055,927	25.09
1914	35,644	686,675	19.26
1915	29,920	573,180	19.22
1916	43,170½	1,151,720	26.68
Totals	307,617½	$7,315,969	$23.80

The low average prices for 1914 and 1915 reflect the temporary depression of values to which most of the diggers were forced to submit, as they could not well afford to hold their diamonds until a recovery of the market.

Work in the alluvial deposits of the South African Union has been very active in the past year, five or six mines in the Orange Free State having produced a total value of £723,453 in diamonds, or $3,519,600, the average per carat being $16.05. The Vaal River diggings furnished 167,620 carats with a worth of £948,571, or $4,592,788; this amount has been exceeded in only two of the previous years, and gives a carat value of £5 13s. 2d. or $27.53, while at the prices ruling in 1914 or 1915 the carat was worth only about £4 or $19.46. Another productive district in this field was Barkeley West, where 82,968 carats of diamonds were produced, the value being £554,896 ($2,699,569), the single carat being therefore worth £6 13s. 9d. or $32.54. Lastly from the new fields of

Klerksdorf came a quarter of a million carats valued at £5 6s. a carat or $25.78.[1]

One of the late developments in South African diamond mining has been the opening up of fields in the Theumissen district by the Compound Mining Syndicate, Ltd. As a result of prospecting operations here a parcel of diamonds weighing 250 carats has been shown. A new company, named New Compound Diamonds, Ltd., is to be formed to acquire the assets of the company named above, and carry on its work.[2] Another new exploitation is that of the Aliwal Diamond Prospecting Syndicate, Ltd., which owns rights on two farms situated south of the Orange River. The prospects here are said to be very promising. The company is registered as a limited liability corporation with a capitalization of £5000, and active operations are likely to be soon begun.[3]

A new diamond corporation, the Monteleo Diamonds, Ltd., has recently been registered in South Africa, in the Orange Free State, with a nominal capital of £45,000. The issued capital is £22,078 and the working capital £6328, leaving a reserve capital of £22,922. The company's property consists of an option to buy 200 morgan (about 422 acres) of the freehold farm Erfbloem No. 712, District Winburg, Orange Free State. The sum of £15,000 in cash for the right and option to purchase, was to be provided by the issue of 15,000 shares, 750 shares serving as part consideration for an extension of the option for one year.

Although as yet only 12 claims of the Monteleo diamond property have been stripped of overburden, the chairman of the company believes that the diamantiferous area equals at least 40 claims. A test washing of 2000 loads yielded the high average of 20 carats to the load, the stones bringing over 70s. per carat. The installation of adequate machinery for speedily stripping the mine will soon be accomplished. The discovery of a single gem of unusual brilliance and purity has been announced, without, however, any information regarding its exact weight.[4]

In the Twenty-eighth Report of the De Beers Consolidated Mines Ltd., for the year ending June 30, 1916, clear evidence is given of the bettering conditions that now obtain in this great South African diamond field. While in the year ending June 30, 1915, the receipts from diamonds sold, less the decrease in stocks taken at cost of production, amounted to but £574,398, the figures for 1916 are £2,142,092, nearly four times as much. Since the decrease for the year in diamonds unsold, at cost, amounts to £502,255, the amount actually received from the diamond sales was £2,644,347. Adding to this "interest and dividends on invest-

[1] *Eng. Min. Jour.*, June 9, 1917.
[2] *So. Afr. Min. Jour.*, July 8, 1916.
[3] *Idem*, Oct. 28, 1916.
[4] *So. Afr. Min. Jour.*, Jan. 27, 1917.

ments," £130,078, "net revenues from rents," £2941, "revenue from other sources," £22,671, and the previous balance of £289,264, we have a total revenue amounting to £3,089,301. Against this must be set the following expenditures: Mining expenditure during period of production, £395,850; expenditure on farms, Kimberley-Alexandersfontein tramway and charges, including donations, £145,932; interest on company's 4½ per cent. South African Exploration debentures, and on capital of leased companies, £169,890; sinking fund for repayment of debentures, £72,893; mining profit tax, estimated, £150,000; British income tax, £9136; expenditure consequent upon the war, £316,660; total, £1,260,461. This leaves a balance of £1,828,840. Preference shareholders received out of the balance the dividend of 10s. per share due for the half year ending Dec. 31, 1914, and a dividend of 20s. per share for 1915, representing £400,000 and £800,000, together £1,200,000; the balance, £628,840, was carried to the next year.

The first dividend declared on the deferred (common) shares of the De Beers Consolidated Mines, since the beginning of the war, has been announced for the year ending June 30, 1917. It will be 40 per cent., a dividend as large as has ever been declared at one time. The directors have also voted the sum of $125,000 for the British Red Cross funds and the same sum for those of the French Red Cross. That the company is now able to disburse so large a dividend, amounting to $5,000,000, forcibly illustrates the recovery of the diamond industry, mainly due to buying for the United States.

The following figures give the stocks of blue ground and lumps on the floors of the respective mines, on June 30, 1916:

	Loads.
De Beers	48,396
Wesselton	2,607,097
Bultfontein	2,379,211
Dutoitspan	4,594,272
Total	9,628,976

To the prospective yield of this diamond-bearing material must be added the stock of unsold diamonds on hand, worth at cost of production, £648,734, and marketable at a much higher figure.

The gradual resumption of operations at the De Beers mines is reflected in the following figures for the years 1913–1914, 1914–1915, and 1915–1916. In 1914–1915 work was done only from July 1 to Aug. 8, 1914:

DE BEERS AND KIMBERLEY MINES

	Loads of Blue Ground Hoisted.	Loads of Blue. Ground Washed.	Carats of Diamonds Found.	Selling Value per Carat.
1913–1914	None	75,815	27,346½	80s. 10.21d.
1914–1915	None	None	None	None
1915–1916	None	None	None	None

WESSELTON MINE

1913–1914	2,373,522	2,083,352	593,305	45s. 7.62d.
1914–1915	217,483	219,276	56,359¼	37s. 7.13d.
1915–1916	43,586	885,334	227,914¼	44s. 2.31d.

BULTFONTEIN MINE

1913–1914	2,279,838	2,069,552	785,510¾	40s. 10.47d.
1914–1915	256.950	214,522	76,084	33s. 6.86d.
1915–1916	60,997	864,052	342,676½	39s. 11.09d.

DUTOITSPAN MINE

1913–1914	2,513,469	2,412,679	497,459	84s. 0.9d.
1914–1915	264,039	260,024	55,609¾	68s. 6.25d.
1915–1916	None	108,597	20,740¼	91s. 0.26d.

GRAND TOTALS FOR ALL MINES

1913–1914	7,166,829	6,641,398	1,903,621¼
1914–1915	738,472	693,822	188,053
1915–1916	104,583	1,857,983	591,331

It will be noted that while but little additional blue ground was hoisted, nearly three times as much was washed in the year 1915–1916 as in the short working period of the previous year. Thus the diamonds recovered came almost entirely from ground already on the floors. This is shown in the number of loads, excluding lumps, on the floor at the close of the 3 years. The number of carats found in the loads washed, and the value per load, are also given, the latter figures depending of course not only upon the quantity of diamonds recovered, but also upon their value in each year:

DE BEERS MINE

	Carats per 100 Loads.	Value per Load.	Loads of Blue Ground on the Floor at Close of Year.
1913–1914	36	29s. 1.28d.	48,396
1914–1915	....	....	48,396
1915–1916	....	....	48,396

WESSELTON MINE

	Carats per 100 Loads.	Value per Load.	Loads of Blue Ground on the Floor at Close of Year.
1913–1914	28	12s. 9.33d.	3,450,638
1914–1915	26	9s. 9.29d.	3,448,845
1915–1916	26	11s. 5.8d.	2,607,097

BULTFONTEIN MINE

	Carats per 100 Loads.	Value per Load.	Loads of Blue Ground on the Floor at Close of Year.
1913–1914	38	15s. 6.38d.	3,095,893
1914–1915	35	11s. 9d.	3,138,321
1915–1916	40	15s. 11.6d.	2,335,266

DUTOITSPAN MINE

	Carats per 100 Loads.	Value per Load.	Loads of Blue Ground on the Floor at Close of Year.
1913–1914	21	17s. 7.87d.	4,358,185
1914–1915	20	13s. 8.45d.	4,341,900
1915–1916	19	17s. 3.48d.	4,233,303

These figures show the quick recovery of the diamond market from the temporary depression in the first months of the war.

The depths of the various shafts remain unchanged, as follows:

	Feet.
De Beers:	
Rock shaft	2,640
No. 1 shaft	1,728
Kimberley:	
Main rock shaft	3,601
Atkins shaft	1,009
Wesselton:	
No. 1 main rock shaft	1,119
No. 2 main rock shaft	1,667
Bultfontein:	
No. 1 main rock shaft	708
No. 2 main rock shaft	1,715
Dutoitspan:	
No. 1 main rock shaft	1,424
No. 2 main rock shaft	768

The only development work for the year 1915–1916 was at the Dutoitspan mine, where 931 ft. of tunnels were driven in the rock, and 44 ft. of passes sunk in the rock. The number of natives employed on July 1, 1915, was 1249, and on June 30, 1916, 6656, an increase of 5407 for the year. The white employees numbered 726 men and 42 lads, July 1, 1915, and on June 30, 1916, 1306 men and 97 lads, an increase of 580 men and 55 lads. This excludes the 526 white employees who were on active military service. From July 1, 1916, all employees have been in receipt of full pay.

The blue ground in sight at the different mines of the De Beers Consolidated Co. on June 30, 1916, was as follows:

Mine.	No. of Loads.
De Beers, above 2,040-ft. level	2,750,000
Kimberley, above 3,520-ft. level	2,000,000
Wesselton, above 980-ft. level	15,738,000
Bultfontein, above 1,000-ft. level	10,182,000
Dutoitspan, above 750-ft. level	13,245,000
Total	43,915,000

Additional, estimated, quantities of blue ground were:

Mine.	No. of Loads.
Wesselton between 980-ft. and 1,550-ft. levels	22,000,000
Bultfontein between 1,000-ft. and 1,600-ft. levels	22,000,000
Dutoitspan between 750-ft. and 1,300-ft. levels	25,000,000
Total	69,000,000

This makes a grand total of 112,915,000 loads in sight and estimated, the diamond content being, on the basis of the latest results, about 32,000,000 carats, worth in the neighborhood of $400,000,000.

The New Jagersfontein Co. sold, in the 3 years immediately preceding the war, diamonds to the value of £3,538,076, making a yearly average of £1,179,359. On the other hand, the total sales for nearly 2 years, up to July, 1916, totaled only £179,900, or less than £90,000 per annum, no diamonds having been sold from the war's outbreak until the end of May, 1915. However, this restriction of sales has served eventually to sustain prices, while the river diggers, being obliged to realize on their product, had to be satisfied with prices often 50 per cent. lower than in 1913 on their forced sales. The Jagersfontein Co. received substantial support in tiding over the difficult period from the National Bank, as well as from Barnato Bros., and the directors were thus enabled to care for their employees during the suspension of work. The recovery, or rather the increase in diamond values over those prevailing just before the war, will soon relieve the situation entirely. From the blue ground already on the Jagersfontein floors, a yield of diamonds worth £1,100,000 is expected, giving probably £500,000 profits for the company's surplus, and making it possible to indemnify the stockholders for the more than 2 years' suspension of dividends.[1] The company resumed dividend paying toward the end of 1916, when a distribution of 3s. per share, 15 per cent., was made to shareholders. The last dividend previous to this was one of 12½ per cent. in April, 1914, none having been paid in the interval.

At the annual meeting of the shareholders, held on Friday, June 30, 1916, the chairman, Sir David Harris, called attention to the unfavor-

[1] The New Jagersfontein Mining and Exploration Co., Ltd., *Twenty-eighth Annual Report for the year ended 31st March, 1916*, Kimberley, 1916.

able result of the forced sale of alluvial diamonds by the diggers as indicating clearly what would have been the effect if the large diamond producers had insisted upon unloading their stocks upon an unwilling market. In his opinion "the policy of the three large producers to stop production, and the action of the Diamond Syndicate in not offering any of its large stock, saved the situation, with the result that prices for the better qualities are as high to-day as in 1913, when they reached high-water mark." He recognized that the production of the Jagersfontein Co., as well as that of the other large concerns, would be strictly limited to the lessened demand. The erection of a new direct-treatment plant was projected, together with a power station, the cost being approximately £300,000. When this plant shall have been installed, it is expected that a saving of at least 6d. will be realized on the working cost of each load of 16 cu. ft. of diamantiferous soil, a saving that will serve to offset the added expense entailed by the increased depth of the working levels.

The number of loads of blue ground deposited on the floors of the Jagersfontein mine in the years 1909–1916 (each year ending Mar. 31), the number of loads washed, the number of carats of diamonds produced, the average yield per load and the total value of the diamonds, were as follows:

Year.	Loads of Blue Ground Deposited.	Loads Washed Including Lumps.	No. of Carats of Diamonds Produced.	Average Yield per 100 Loads (of Blue).	Total Value of Diamonds.
1909	1,526,018	2,270,651	224,204¼	12.39	£140,346
1910	2,431,069	3,236,590	338,581½	13.08	1,023,187
1911	2,479,715	3,436,283	333,831¼	11.47	993,779
1912	3,479,648	3,798,831	344,635¼	10.62	1,116,432
1913	4,558,383	4,173,753	363,397½	9.99	1,259,983
1914	3,316,628	4,403,383	330,523¾	8.90	1,161,660
1915	1,173,927	1,655,337	116,251½	8.24	270,175
1916	....	325,366	24,587¾	8.57	75,101
Totals	18,965,388	23,300,194	2,076,012¾		£6,310,663

The diamonds of the recently operated Kameelfontein digging averaged 0.83 carat in weight during last June, and had an average worth of £3 6s. 9d. per carat. One diamond weighing 37 carats was found, its value being £300. A few fine stones of 7 and 9 carats, and one of 12½ carats have been reported, but in general the diamonds are not of good quality, many broken stones and cleavage fragments appearing. Occasionally heart-shaped twin crystals are found here. The prevailing tint is brownish or yellowish; a few pale green stones have also been recovered. The peculiar opalescence characteristic of the Premier mine diamonds is present in the case of many of those from Kameelfontein. This would seem to indicate that the deposits have resulted mainly from denudation of the Premier pipe, this source being perhaps supplemented from other primary deposits. It is stated that nothing indicates the proximity of a kimberlite occurrence.[1]

At the great Premier mine, washing operations which had been discontinued from August, 1914, were resumed on a small scale in January, 1916, and were continued without interruption throughout the year. Hauling and washing of mine ground were started late in July, 1916.[2] The larger part of the diamonds recovered came from an old heap of tailings and cylinder lumps dumped in the early history of the company; this furnished 266,945½ carats, while from the mine ground 153,001½ were secured. These diamonds, except those carried over in the Suspense Account, and the whole of the stock on hand on Oct. 31, 1915, were so carefully and conservatively marketed that better prices were obtained than those ruling just before the outbreak of the war.

The total number of natives admitted to the compound was 9157, a large number (5775) having applied for work on their own account, a successful result of the company's efforts to encourage voluntary labor. The agents in the various labor districts furnished the balance of the workers, to the number of 3382. The close of the financial year found 6500 natives employed. The death rate among them was low, being but 13.55 per thousand per annum.

The average depth of the mine is now 235 ft. The ground still available above the 360-ft. level is sufficient to supply material at the normal rate of working for 3 years.

The total number of loads of blue ground taken from the mine during the few months of actual mining from July 29 to Oct. 31, came from the following levels:

From the 210-ft. level	149,058
From the 260-ft. level	222,713
From the 310-ft. level	363,462
From the 360-ft. level	119,552
	854,785
Add to this tailings and cylinder lumps	717,736
Total washed	1,572,521

The average yield per load of the mine ground washed was 0.179 carat per load, showing that the slow diminution of the yield continues, the average for 1914 having been 0.185 carat per load. The better showing for the whole of the material washed (0.267 carat per load) resulted from the greater yield of the old tailings.

The profits derived from the sale of diamonds, £475,856, served to defray mine expenses of £185,827, administrative expenses of £13,572, directors' and auditors' fees of £5325, as well as to provide £2500 for

[1] *So. Afr. Min. Jour.*, July 15, 1916.

[2] *Fourteenth Annual Report of the Premier (Transvaal) Diamond Mining Co., Ltd.* Directors' report and statement of accounts for the 12 months ended 31st October, 1916.

depreciation on investments, leaving a balance of £268,632. Adding to this profit suspense as of Oct. 31, 1915, to the amount of £234,298, and deducting diamond stock on hand, Oct. 31, 1916, valued at £160,330, there remained £342,600 for transfer to Expenditure and Revenue Account No. 2. Deducting here £5289 for general equipment, and setting aside 60 per cent. of the balance as the share due to the Government of the Union of South Africa, there was left for the shareholders £134,924. From this the two preference dividends of £50,000 each, still due from 1915, were paid, as well as £12,110 for British and South African income tax, and there remained enough to show a balance of £77,440 as against a balance of £54,626 at the close of the previous financial year.

Full details of the total diamond production of the Premier from the outset to Oct. 31, 1916, are given as follows in the 14th Annual Report:

Year Ended Oct. 31.	No. of Loads Washed.	No. of Carats Found.	Value of Diamonds.	Yield Per Load in Carats.	Value Per Carat.	Value Per Load.	Cost of Production Per Load.	Profit Per Load.
			£		s. d.	s. d.	s. d.	s. d.
1903	76,931	99,208¼	137,435	1.290	27 8.50	35 6.70	4 7.20	30 11.50
1904	939,265	749,653½	866,030	0.798	23 1.20	18 5.30	2 7.62	15 9.68
1905	1,388,071	845,652	994,687	0.609	23 6.29	14 3.98	3 3.44	11 0.55
1906	2,988,471	899,746	1,277,740	0.301	28 4.82	8 6.61	3 5.71	5 0.90
1907	6,538,669	1,889,986¾	1,702,631	0.290	18 0.20	5 2.49	2 4.14	2 10.35
1908	8,058,844	2,078,825¼	1,536,720	0.258	14 9.40	3 9.75	1 10.24	1 11.51
1909	7,517,793	1,872,136½	1,172,379	0.249	12 6.29	3 1.43	1 11.42	1 2.01
1910	9,331,882	2,145,832¾	1,496,641	0.230	13 11.39	3 2.49	2 0.56	1 1.93
1911	8,325,272	1,774,206	1,433,971	0.213	16 1.97	3 5.34	2 2.02	1 3.32
1912	9,707,098	1,992,474	2,004,943	0.205	20 1.50	4 1.57	2 4.79	1 8.78
1913	10,434,680	2,107,983	2,336,828	0.202	22 2.05	4 5.74	2 6.67	1 11.07
1914	7,683,943	1,417,755	1,259,643	0.185	17 9.23	3 3.34	2 5.89	9.45
1915	Mining operations suspended.							
1916	1,572,521	419,947	475,856	0.267	22 7.95	6 0.63	2 7.62	3 5.01

This gives the following totals for the fourteen years:

Number of loads washed.................................... 74,563,440
Carats of diamonds found.................................. 18,293,406
Value of diamonds..£16,695,504

It is stated that in line with the general policy to restrict and control the diamond market, the washings of the Premier mine are to be confined to the capacity of the No. 4 Gear, and also that the customary annual increase in the depth of the open-cut workings, which has been 34 ft., will be reduced one-half to 17 ft. As a result of this the duration of the mine would be double what it would be if the old rate were maintained.[1]

The third report of the South African Diamond Corporation, Ltd., for the year ending June 30, 1916, was submitted at the general meeting held Dec. 19, 1916. There has been no change in the capital of the company, which remains at £1,000,000, of which £100,000 has been issued, that is, two directors' shares of £1000, and 98,000 common shares of £1 each. Washing had been resumed in March, 1916, and as the results

[1] *Eng. Min. Jour.*, June 9, 1917.

were satisfactory and profits equalled those realized before the war, the company has begun again the payment of dividends. Digging has been carried on to some extent, but has been hampered by the absence of many diggers who are serving in the army. The diamond trade has been very active during 1916, the demand coming largely from the United States, but being also notable in Russia, India, and the Far East. At the Blaauwbosch mine, in which this corporation is interested, washing has been in progress since March. The rise of about 20 per cent. in diamond prices as compared with the period before the war has operated to enhance the value of diamond-mining shares in the market.[1]

Australia.—Some diamonds have been found from time to time in the course of mining operations in the Beechworth district, Victoria, Australia. Quite recently a prospector came across a number of them, while sluicing in Blacksand Creek, four miles from Beechworth, and the principal of the Beechworth Technical School has pronounced one of them to be a first-water diamond of 5 carats. In the district from Wooragee down to Eldorado diamonds have also been met with, but as the stones were very small, the product was trifling. Some time ago a 5-carat stone was found in the Beechworth district, so that two such diamonds may now be credited to this locality. It is supposed that the matrix of the original deposit is to be sought at some point not far distant from Beechworth. Of other diamond finds in Australia in recent years there may be noted the finding of 11 small diamonds in the sluice boxes at the Great Southern Alluvial mine, Chiltern, in 1912. Still another diamond-producing locality is the granite country at Kongbool, in the Western district, and also Bunyip and Benalla. In New South Wales there are diamantiferous deposits at Cudegong, Bingara, Tingha, Mount Oberon, and in the Inverall district. The largest diamond of which Australia can boast was found on Mount Werong, near Oberon, New South Wales; this weighed $28\frac{5}{16}$ carats (29.32 metric carats). The finest stone, however, came from the Echunga field, South Australia, and is called "Glover's Diamond"; it brought £70. A few diamonds have also been furnished by the Pilbara district of Western Australia. The official statistics estimate the diamond yield of 1914 at 1580 carats, with a value of £1440, and place the total production of Australia up to the end of 1914, at 186,124 carats, worth £126,989.[2] This gives about $617,800 as Australia's share of the diamond production of the world.

A few diamonds have been found in the sapphire-bearing gravels of the Anakie district, Queensland, Australia. Some years ago a colorless, flawless diamond crystal weighing $1\frac{1}{4}$ carats was found in Policeman

[1] *So. Afr. Min. Jour.*, Dec. 30, 1916.
[2] *The Watchmaker, Jeweler, Silversmith and Optician*, May, 1917, p. 519.

Creek, and two straw-colored diamonds weighing about 1 carat each are reported to have been found in Retreat Creek, the locality where sapphire was first discovered in this region.[1]

Brazil.—Of the most favored regions for diamond mining in Brazil at the present time, Consul General Gottschalk reports as follows:[2]

"In the State of São Paulo diamonds have been found in the Rio Verde and Sapucahy-Mirim. In the State of Parana, the Tibagy, Japão, Pitanguy Rivers, and their affluents have shown some results in diamond working. The interior of the State of Bahia seems to have been, with Minas Geraes, the most favored region. It was in the Sincora and Chapa Mountains, in the Paraguassu River and its tributaries, in the mountain chain called Lavras Diamantinas, at Andarahy, Morro do Chapeu, Salombro, Cannavieiras, and Itapicuru that diamond fields were found which, since 1844, have been yielding the precious stones in great quantities. It is said that during the decade between 1844 and 1854 the customs at the port of Bahia registered 876,250 carats of diamonds.

"In the district mentioned the famous Brazilian carbonados, or black diamonds, have been found. They are also present in the north of the State of Minas Geraes, at Grão-Mogol and Terra Branca, but most have come from Bahia. Lençoes in that State produced in 1895 the great carbonado which is said to have been sold successively for $6000 and $25,000.

"The diamonds of the State of Goyaz, Brazil, found in the beds of the Claro, Piloes, Fortuna, Tres Barras, Desengano, and Caiaposinho Rivers, are stated to be distinguished by amber or clear green tints. They are present in but limited quantity.

"The native diamond miners in Brazil are said to exhibit an unusual degree of trustfulness in sending the rough stones to the coast. To certain business men, with whose good repute the sender is, however, probably acquainted, packets of uncut stones are intrusted, without the exaction of any receipt. This brings it about that many Brazilian diamonds reach the coast without being included in official statistics. It is said that before the war, when Germans were the principal diamond traders, they frequently employed Syrians, settled in the interior, as brokers and intermediaries; some of the German travelers, however, made their purchases directly at the mines. Now American firms are sending representatives, and it is not unlikely that they will keep the trade in their hands even after the conclusion of peace has again opened up trade relations between Brazil and Germany. However, there are apparently no American diamond miners in the country as yet.

"Diamond buying in Brazil in the period before the beginning of the world war was principally in the hands of Germans, their intermediaries with the miners being usually certain Syrians who had settled in the interior of the country. However, in some cases German traveling buyers dealt directly with the buyers. Since the outbreak of the war several American firms have sent agents to Brazil, and in view of the great demand for diamonds in the United States and the high prices, it is deemed probable that the Americans are likely to drive competitors out of this market."

British Guiana.—The diamond production of British Guiana for the year ending June 30, 1915, was 78,533 stones weighing 10,980 carats, against 94,871 stones weighing 12,506 carats in 1913–1914.[3] The average

[1] *Bulletin of the Imperial Institute*, April-June, 1916, p. 258.
[2] *Comm. Rept*, Sept. 9, 1916.
[3] From *Report of the Institute of Mines and Forests of British Guiana*, for 1915.

weight for 1914–1915 was thus 0.14 carat against 0.132 carat for 1913–1914, a slight increase. At a price of $10 per carat which has been given as the estimated value there were recovered in 1913–1914 diamonds worth $125,060, while for 1914–1915 the value was but $109,800, or $15,260 less. The progressive changes in average weight since 1910 were as follows:

	Carat.
1910–1911	0.130
1911–1912	0.085
1912–1913	0.100
1913–1914	0.132
1914–1915	0.140

India.—What an infinitesimal contribution to the diamond supply is now made by India, once the sole source of the world's diamonds, is strikingly brought out in the annual report for 1915 on the Mineral Production of India. The figures there given for 1914 and 1915 are as follows, and seem to indicate that the output is dwindling away to the vanishing point.

	1914.		1915.	
	Carats.	Value.	Carats.	Value.
Central India	54.65	£791 ($3,848)	35.99	£603 ($2,933)

The opinion prevails that the deep-lying Indian diamond deposits were never reached by the diamond miners of former times, and that a systematic exploitation of some of the old fields would give good results. The Geological Survey of India has for some time past carried on investigations to this end, and considerable interest has already been aroused in the matter. Whether the diamond material would prove to be present in sufficient quantity to warrant the expenditure necessary for equipment and working on a large scale must, however, be regarded as rather doubtful, in view of the powerful competition of the South African companies.

California.—Diamonds have been found at several localities in the State of California, as follows:[1]

In El Dorado County, at Placerville, on the south side of Webber hill, in White Rock canyon, at Dirty Flat, and at Smith's Flat; in Amador County, at Rancheria, 3 miles south of Volcano, and at Loafer Hill, near Oleta; in Nevada County, at French Cowal; in Butte County, at Cherokee Flat and at Yankee Hill; in Plumas County, at Gopher Hill, and on Upper Spanish Creek. From three other counties, Del Norte, Trinity, and Tulare, reports of diamond finds have come.

The writer has suggested the advisability of equipping the washings on the California districts where diamonds have occurred with tallowed boards such as are used for the concentrates of the South African mines.[2]

[1] H. W. Turner in *American Geologist*, **23**, (1899).
[2] *Min. Sci. Press*, Feb. 24, 1917, noted in paper by W. H. Storms on Diamonds in California.

Emerald

In the Budget for 1917–1918 of the Republic of Colombia there appears among the items of expected revenue, one of $200,000 for receipts on account of the emerald mines of Muzo and Coscuez. This appears in an executive decree published in the issue of the Diario Oficial for Feb. 15, 1917.[1]

A rare and interesting type of emerald crystal of the kind locally known as "emerald twins," was brought from the Muzo district by Dr. Pogue. The specimen he secured measured about 1½ cm. in length and about 7 mm. in diameter. He describes it as a crystal with a tapering core of carbonaceous emerald, with six rays of carbonaceous material extending from the edges of the core to the corners of the crystals.

The common emerald is found in several parts of German Southwest Africa, and occurs, associated with tantalite, in pegmatite veins at Tonkerkoek. Near Rossing there is found in pegmatites golden beryl, or "heliodore," accompanied by tourmaline and tungsten.[2]

Garnet

A remarkable crystal of almandine garnet was found while grading a property between Broadway and Fort Washington Avenue, 166th to 168th Streets, during the summer of 1915. The crystal shows about eight of the twenty-four faces of a trapezohedron; the balance is imperfect, with slight rock adhering. It weighs 10 lb. 8 oz. avoirdupois, 13 lb. 12 oz. troy, or 4.763 kg.

The crystal has been lent to the New York Mineralogical Club to be placed with the Collection of Minerals of New York City in the Museum of Natural History, by Charles W. McDonald, the contractor who found it. This brings to mind the great almandine garnet found at 35th Street, Manhattan, and which weighed 9⅔ lb.[3] It is now deposited in the New York Mineralogical Club collection.

Many fine gem garnets of the rich pyrope variety have been found in the Navajo Reservation in Arizona and Utah. In this region more or less extensive garnet deposits occur at three localities, two of which have been named Mule Ear, and Moses Rock, in Utah, and the third, called Garnet Ridge, in Arizona. From time to time brilliant examples have been picked up by Navajo Indians and sold to traders, who took them to the trading posts where they were offered for sale as "Arizona rubies." Of the three principal localities above mentioned, the Mule Ear deposits

[1] *Comm. Rept.*, May 3, 1917.
[2] *L'Echo des Mines*, Sept. 24, 1916, in article on the resources of German Southwest Africa.
[3] See "Gems and Precious Stones of North America," by George F. Kunz, pl. opp. p. 82.

do not yield much good material. In the Moses Rock district the strong southwest winds help the garnet-seekers by shifting the sands covering the garnet-bearing drift and exposing the precious material to view. At Garnet Ridge the garnet material is exposed by the strong winds and is found strewn over the surface or accumulated in pockets and riffles; this is the most promising field for the garnet-seekers. It often happens that within 5 min. a quart measure can be filled with material gathered from a natural riffle, fully one-half of the contents being garnet. Masses of solid garnet measuring sometimes as much as 4 in. in diameter have been found. The garnetiferous drift of a high central area has been spread by running water over the surrounding slopes.[1]

Jadeite

The official figures on Burmese jadeite are somewhat puzzling. The production for 1914 and 1915 and its value appear as follows:

	1914.		1915.	
	Carats.	Value.	Carats.	Value.
Myitkyina.................	3,764.75	£13,643	3,692.75	£12,678

On the other hand, the exports from Burma for these 2 years are thus reported:

1914.		1915.	
Carats.	Value.	Carats.	Value.
2,959	£40,092	5,001	£52,070

These figures regarding exports are believed to be more likely to indicate the true condition of the jadeite industry than those relating to production or the mining value and the dealers' selling export price.[2]

Opal

The precious opal of Hôsaka is briefly noted by *Yônosuke Otsuki* (pp. 274, 275). The locality lies in the upper course of the rivulet Kikôzugawa, which flows between the village of Hôkawa and the mountain-pass Kurumatôge. The opals are found within nodules (silicified spherulites) enclosed in a greenback pearlite which turns gray in weathering. The nodules are usually from 3 to 5 cm. in diameter, although some measure as much as 18 cm. across; they are brownish or black, resembling potatoes in shape, good opals coming more frequently from the brown than from the black nodules. The opal-material is here present in great variety: milk opal, opal-agate, precious opal, glass opal, as well as the smoky, obsidian-like variety, the yellowish-green, the waxy and others. Im-

[1] Herbert E. Gregory, Garnet Deposits on the Navajo Reservation, Arizona and Utah. Reprint from *Econ. Geol.*, April-May, 1916.

[2] H. H. Hayden, The Mineral Production of India During 1915. Geological Survey of India.

portant is the granulated appearance of some specimens when viewed in a particular direction, the granules offering one interference color by incident light, while the cement assumes a different color. The specific gravity of the precious opal is 2.22, its hardness 5.5 and its aqueous content 8.49 per cent.

A recent discovery of precious opal at Stuarts' Range in Southern Australia has been pronounced to be perhaps the most important mineral discovery in that province made for many years. The area over which opal has already been found in this new field has a maximum length of about ten miles and a minimum width of about two miles, indicating a district of at least twenty square miles in extent. Further exploration here, when rendered practicable by better local supplies of water, is expected to considerably extend this field, which is accessible either by the northern or the transcontinental railway.[1]

Pearls

Australia.—A Federal Royal Commission has been charged, for the past 6 years, with the investigation of the pearling industry on the northwestern and northeastern coasts of Australia. It is conjectured that the disposition heretofore prevailing to confine the exploitation entirely to white labor, may find itself modified by the war conditions when the Commission finally presents its report to the Federal Parliament. At the time of its appointment in 1912 the following subjects were defined for inquiry:

1. The classes of labor now engaged in the industry.
2. The reason why white labor has not been generally employed heretofore.
3. The practicability of the introduction of white labor.
4. The employment of machinery in connection with diving pumps.
5. The cultivation of the pearl-shell oyster.
6. The means to be adopted to encourage white labor either wholly or partially.

In attempting to decide the important question as to the desirability of a rigid exclusion of black labor, the Commission carefully studied the conditions obtaining at Broome and Thursday Island, localities where many black workers are used, and Japanese also. The conclusion arrived at is believed to favor the maintenance of existing arrangements in this respect, with slight modifications and restrictions.

The physical capability of Europeans for diving was found to compare favorably with that of other races, but the same could not be said

[1] *The Watchmaker, Jeweler, Silversmith and Optician,* June, 1917, p. 597.

of their ability to utilize the necessarily restricted period of their immersion in locating the pearl-mussels. In this respect the Asiatic pearl-diver possesses an inherited, and almost instinctive ability. So earnest, however, is the desire of the Australians to dispense with other than white labor, that it has been proposed to raise the scale of wages, so as to make pearling an especially attractive employment; it has also been proposed to give a bonus per ton on shell raised by European divers and crews, in the belief that the desired end would be attained by this added expense. The commissioners did not, however, favor the carrying out of such plans.[1]

The artificial production of pearls by special shell cultivation has been the subject of experiment at Montebello Island, but it was given up for lack of capital. The work was to be pursued upon the same lines as in Japanese and Indian waters where a certain measure of success has been attained. The Australian commissioners, however, believed that fuller information should be secured as to the methods employed in Japan and India, before undertaking work in Australia on a considerable scale, but they did not advise that any appropriation for this purpose should be made by the Commonwealth Government, not regarding Australian pearling as an industry of sufficient importance to warrant this.

Canada.—Of late years some fresh-water pearls of good quality have been brought from the rivers of Labrador, an exceptionally fine specimen having been sold for over $1000. An attractive pair of pink pearls are also reported to have been found in this region, each pearl weighing about 12 grains, the value of the pair being estimated at from $120 to $140. They were found by chance in a single shell by a man who was opening a clump of shells at haphazard with his pocket knife. As a rule, the pearl-seekers lay out the mussels on flat rocks or on sand banks, leaving them there until the flesh decomposes so that the shells open and the interior can be examined without trouble. The Labrador Indians are said to have long known that pearls were to be found in their rivers, and for generations pearl-seeking was carried on by them. The older pearls in their possession have, however, practically lost their value, having been unskilfully pierced for attachment to wampum belts or for stringing as necklaces. At the present time the Indians find ready sale for any pearls they may find to the Hudson Bay traders. The pearl industry here is important enough to induce the sending of buying agents from several of the Montreal gem-dealing houses.[2]

India.—Pearls constituting the greater part of the produce of the Indian pearl-fisheries for 1916 are said to have been restored to their

[1] *The Christian Science Monitor's* special Australian correspondent.
[2] *Jewelers' Circular Weekly*, Dec. 20, 1916.

native element at the destruction by a submarine of the British Steamship "Arabic" in the Mediterranean last November. The pearl market is now and has been for some time past largely dependent upon the supply of pearls derived from necklaces and other ornaments that can be bought from their present owners. The ebb and flow of wealth characterizing the present world conflict has in many cases forced the owners of fine pearls to seek a purchaser for them, and little difficulty has been experienced in making good terms, as the gem-dealers' stocks are constantly being exhausted by the increasing demand for these beautiful natural products.

It has been stated that the consignment of Indian pearls on the "Arabic" was worth $1,250,000, and the report goes that it was fully insured, the insurance being promptly paid when the fact was established that there was no chance for salvage, on account of the great depth of water in which the ship was sunk.

Persia.—The pearl export trade in the Persian seaport of Lingah has almost come to a standstill. It has been adversely affected for several years by the diversion of a great part of this trade to Bahrain, to which many of the English and Indian pearl-merchants resort annually to make their purchases, and now the general discouragement of commerce and trade in Persia, due to the fact that a considerable part of that land has been the scene of military operations, has accelerated the decline of Lingah. For the Persian official year ending Mar. 20, 1915, the pearl exports were worth only $22,750, against the sum of $112,950 in 1913–1914, at that time regarded as an exceptionally bad showing; in 1912–1913 pearls to the value of $330,225 were exported. Another unfavorable condition for this port is that Debai has been made a regular port of call for the boats of the British India Steam Navigation Co., as goods from Oman are now taken directly to that port.[1]

United States.—The pearl yield from American rivers, such as the Mississippi, Illinois, Wabash, etc., in 1916, was only about one-third of that reported in normal years. Disadvantageous circumstances were the late advent of Spring, and the prevalence of high water, which impeded the operations of the pearl-seekers. This curtailment of the American supply coupled with the greatly diminished Indian output has resulted in an advance of fully 25 per cent. in the price of American pearls. The total value of those secured in the past year has been put at from $200,000 to $250,000.

Rubellite

Rubellite has recently been found in two localities in Lower California, one in the Valley of San Pedro, between Calamahí and San Borja, the other

[1] *Indian (Government) Trade Journal*, Apr. 28, 1916.

at San Juan, near San Borja. Heretofore only black tourmaline crystals, some of very large dimensions, had been discovered in the pegmatites of this region. The rose-colored, lithium tourmalines (rubellites) occur in metamorphosed slates, and have been found in considerable quantity, some of the crystals measuring 10 cm. in length. The tourmalines appear in these biotite slates in crystal aggregates. The color is light pink, the lower part very occasionally green; crystals not affected by weathering are transparent.[1]

Rubies

While according to the Report submitted at the Twenty-Eighth General Meeting, depressing economic conditions continued to affect the business of the Burma Ruby Mines, Ltd., during the year ended Feb. 29, 1916, there was still a notable recovery from the bad showing of the previous year, when the Income and Expenditure Account offered a deficit of £8433 14s. Last year, although there was still a deficit upon the year's operations, this amounted to but £511 3s. 4d., making the total deficiency for both years £8944 17s. 4d.

The sales of rubies amounted to £37,646 13s. against £38,858 14s. 7d. in 1914–1915. The chief element of strength was the good demand both in Burma and India. Conditions and prospects are encouraging enough to warrant the erection of a second washing machine at the Kathi mine, on account of the value of the ruby earth found there. Of course no dividend could be declared during the year and the amount due for royalties to the Government of India, £8799 12s., still remains unsettled. However £500 on a security loan of £3500 was paid, and the entire balance has been liquidated since the close of the year. The stock of rubies on hand, £57,001, is about the same as at the end of the previous year. Because of the French moratorium acceptances of £3500 negotiated on drafts for rubies sold have, for the present, to be regarded as a contingent liability.

The fact that under such favorable circumstances but little further deficit was incurred indicates that with the return of a normal state of affairs this company will be able to resume dividend payments.

The production of precious corundum (ruby, sapphire) and spinel in Burma showed a marked decrease in 1915 as compared with 1914, although perhaps less than might have been expected. Of course rubies represented the major part of the output, but there was also a fair quantity of sapphire, and a considerable amount of the less valuable spinel. The returns from the Mogok mines are here given.

[1] Ernst-Wittich, Über Edelsteinfunde auf der Halbinsel Nieder-Kalifornien; reprint from *Centralblatt für Min., Geol., und Paläont.*, 1914, **15**, 449–456. See also Sectraría del Fomento, Colonización, de Industria: *Memoria de la Comisión del Instituto Geologico de México que exploró la región norte de la Baja California, Mexico*, 1913, p. 327.

	1914.		1915.	
	Weight in Carats.	Value.	Weight in Carats.	Value.
Rubies	193,333	£40,781 ($198,400)	167,904	£34,881 ($169,696)
Sapphires	56,709	2,052 ($9,983)	39,718	1,276 ($6,208)
Spinels	54,830	300 ($1,460)	43,827	141 ($686)
Total	304,875	£43,133 ($209,843)	251,449	£36,298 ($176,590)

Sapphires

Sapphires continue to be very much in demand. However, owing to the shortage of lapidaries in France, the mobilization of many Swiss gem-cutters of the Jura regions, and the increasing demand for labor, and also owing to the isolation of the great German gem-cutting establishments of the Idar and Oberstein regions, only a small number of sapphires were cut during the past year. A considerable amount of Australian material was used for caliber-cut work and flag ornaments, especially the American flag made from rubies, diamonds and sapphires.

The output of the New Mine Sapphire Syndicate, of Utica, Fergus County, Mont., for the year 1916 is given as follows:

Cuttable stones	73,322 carats.
Industrial stones	2,070 oz.

In the Anakie district in Queensland, the chief alluvial sapphire deposits are in the Central, Tomahawk, Boot and Kettle, Policeman, and Retreat Creeks. The first discovery of Australian sapphire was made in the last-named creek. The sapphire-bearing alluvium, sometimes but a few inches thick, has in other places a depth of several feet. The yield varies in the different localities. The Scrub working on Policeman Creek shows a yield per load of ½ oz. of "parcel blues," ¼ oz. of "small blues" (less than 1 carat in weight) and 1½ oz. of "machine stone." Simple methods of recovery are in general use, and the methods of digging consist of "surfacing," the simple removal and treating of the soil, "deep surfacing," which requires the removal of several feet of overburden, and a third method in which shafts are opened through the overburden into the sapphire-bearing gravel. For securing the sapphires hand-raking suffices when the gravel is coarse and the sapphires large enough to be picked out; otherwise the gravel is screened through sieves. Before the outbreak of the war there were more than 300 miners working in the Anakie sapphire deposits.[1]

Recent experiments at the Imperial Institute in Queensland have demonstrated that the transparency of sapphires can be greatly increased

[1] *Bulletin of the Imperial Institute*, April–June, 1916, pp. 259, 260.

by subjecting them to high temperatures. This is held to confirm a suspicion that the former German demand for Anakie sapphires of a deep violet hue, appearing black by artificial light, was due to the employment in Germany of some process for modifying the color.[1]

The cessation of dealings in gems in Australia, due to the war, made 1915 one of the dullest years on record for the sapphire fields of Anakie, Queensland. However, although there was little encouragement for mining operations at this point, the resident lapidary was kept fully occupied with gem-cutting and a considerable quantity of cut gems was sold. Toward the close of the year conditions improved somewhat, with the announcement of a Sydney firm that a market had been secured for sapphires in London; this firm was able to declare that it had no dealings with any enemy country, and was thus privileged to purchase all classes of stones. The Commonwealth of Australia has prohibited the export of gem-stones to any other country than Great Britain.

But little digging was done in the Anakie field during 1915, and the washing machines have not been in operation since August, 1914, such work as has been done in this direction being accomplished by dry-sieving, or hand-washing. Considerable difficulty has been experienced in making even an approximate estimate of the year's sapphire output.

The following figures as to the known sales of sapphires from the Anakie district since 1902 have been supplied from the Queensland Report.

1902	£ 5,000	
1903	6,500	
1904	10,575	
1905	5,255	
1906	18,110	
1907	39,000	Sapphire
	1,500	Corundum
1908	11,800	Sapphire
	2,500	Native stones
	900	Corundum
1909	23,116	
1910	21,116	
1911	16,623	Gem stones
	5,620	Industrial corundum
	500	Sold by individual miners
	1,650	Cut by Lapidaries
1912	40,016	
1913	43,292	(£3,927 recognized as gems and cut in Australia)
1914	15,000	(Six or seven months before the war)
1915	.....	(Industry interrupted by the war)
1916	8,000	Up to July 31st.

This gives a total of sapphire and corundum material from the Anakie field in the 15 years from 1902 to 1916 inclusive of £264, 273 or $1,285,688. The returns for 1912 and 1913 when unusual conditions prevailed indicate an average sapphire production of about $200,000 yearly.

These figures offer an eloquent testimony to the loss in this industry entailed by the war. There was toward the end of the year a good

[1] *Queens. Govt. Min. Jour.*, Feb. 15, 1917.

demand for clean machine stones, sufficient to warrant the belief that the stock now on hand can be satisfactorily marketed. The present population of the fields is put at but 275 persons, a large falling off from the average population in recent years.[1]

Staurolite

A number of staurolites, stones which have enjoyed considerable vogue because of their supposed luck-bringing qualities, are reported to have been secured a short distance from the MacGregor copper mine at Cloncurry, Queensland. The figure of a cross which gives its name to this mineral results from the interpenetration of two crystals at right angles with each other. As the specimens from Cloncurry are said to be of a dull brownish hue, they are hardly of gem-stone quality, those cut for this use being transparent and of a reddish-brown, and occasionally claret-colored.[2]

[1] *Annual Report of the Under Secretary for Mines, Queensland, Australia,* for the year 1915, Brisbane 1916, p. 23, 34.
[2] *Queens. Govt. Min. Jour.,* Sept. 15, 1916.

QUICKSILVER

By Clifford G. Dennis and V. E. Bogard

The opening weeks of 1916 found the quicksilver market continuing in a rapidly upward trend which began during the latter months of 1915. The price of the metal rose steadily from $90 in October, 1915, until the record price of $300 per 75-pound flask was quoted in the last weeks of February, 1916. From the first week in March the price fell rapidly until June, when it reached the price of $75 to $80 per flask, from which it varied but slightly during the remainder of the year.

This very rapid rise and decline of the quicksilver market was very striking, and when compared with the imports and exports which will be mentioned later it is of special interest.

The high prices of quicksilver very strongly invited production, and from all practicable fields the metal was produced, although the activity in development and opening of old properties was hardly so pronounced as in 1915. According to the reports of H. D. McCaskey of the United States Geological Survey, the production of quicksilver reached the greatest quantity since 1904 and the greatest value, with the exception of 1875, in the history of the industry in this country. The production for 1916 was reported as 29,932 flasks of 75 lb. each, valued at an average price of $86.08 per flask, or a total of $2,576,547. These figures show an increase of 42 per cent. in quantity and 46 per cent. in value over those of the previous year.

Of the total domestic production of quicksilver California reported 21,045 flasks, or about 71 per cent. of the total, valued at $1,811,554. Of the remaining 29 per cent. Texas and Nevada produced 8504 flasks, or about 27 per cent., while Oregon and Washington produced the remaining 2 per cent., or 383 flasks.

Among the California producers the New Idria mine in San Bonito County was the largest, with a production of 10,828 flasks. The Alpine with a new 20-ton Scott furnace, the Wonder, Hernandez and Aurora mines of the same county were all operated during the year and produced some metal. Other large producers were the Guadalupe and New Almaden mines in Santa Clara County. At the Oceanic mine in San Louis Obispo County extensive plans were made and rushed to completion for operating on low-grade ores by concentration methods. Some success was experienced; the final outcome of the undertaking, however, can not as yet be definitely ascertained. The Helen mine of Lake County cleaned up a very satisfactory production for the year, as did also the Great Western and Wall Street mines of the same county. In Napa County the Oat Hill mine continued the concentration methods started in 1915, while some production was reported from the Aetna and Knoxville mines. The St. Johns Mine in Solano County reported a successful year and the Hastings mine was operated for a short time, but no production was reported. Other producers were the Great Eastern, Cloverdale, and Culver Bear in Sonoma County, the Reed in Yolo County, the Parkfield in Monterey County, the Mercy in Fresno County, and also the Phoenix and Abbott mines.

In Texas the Chisos mine in Brewster County reported the second largest production in the country. The Big Bend, Mariposa and Colquitt-Tigner mines all produced some metal.

The Goldbanks, Cinnabar King, Red Devils and Lost Steers in Nevada reported considerable, as did also the Nevada Cinnabar Co. and Mercury mines in the Ione district.

From Oregon and Washington a combined production of 383 flasks was reported from the Black Butte, Little Jean, Ranier and Mrs. Dewey properties in Oregon, as well as The Mountain King on Evans Creek, Utah Quicksilver Co. and Bonanza mines from the same district. Washington reports some metal produced from Morton Cinnabar and Mother Lode properties. There was no production reported from Oregon or Washington in 1915, although it was stated that considerable prospecting was being carried on in these districts.

In Arizona it is reported that quite a bit of prospecting was done in the Mazatel district, although no production is reported.

Because of conditions brought about by the war it is impossible to obtain accurate data relative to foreign production of quicksilver. So far as known it may be assumed that the Almaden mines of Spain continued to be the largest producer and put out not less than its normal average production of some 2000 metric tons. The Tuscan mines in Italy undoubtedly produced to capacity, as well as the Idria mines in Austria. The former reported a production in 1915 of 985 tons of metal from 110,642 tons of ore.

According to the Department of Commerce reports the imports for 1916 were 424,396 lb., valued at $515, 919, while the exports were 666,027 lb., valued at $670,475. The exports exceeded the imports for the year by $154,556.

In connection with imports and exports it is very interesting to note the influence of foreign manipulation on our markets, not only of quicksilver, but of other war materials produced in this country and needed by the warring nations. Of our total quicksilver exports for the first three quarters of 1916 only 0.5 per cent. went out during the first quarter, 29.5 per cent. during the second and 70 per cent. during the third quarter, while directly opposite conditions are found in the imports, 57 per cent. coming in during the first quarter, 33 per cent. during the second and only 10 per cent. during the third quarter.

STATISTICS OF QUICKSILVER IN THE UNITED STATES

Year.	Production.					Exports.			Imports.	
	Calif. (*a*)	Texas.	Others.	Total.	Value. (*f*)	Flasks.	Metric Tons.	Value.	Pounds.	Value.
	Flasks.	Flasks.	Flasks.	Metric Tons.						
1902	29,552	5,252	....	1,208	$1,515,714	13,247	459	$575,099	*Nil.*	....
1903	32,094	5,029	....	1,288	1,564,734	17,575	610	719,119	*Nil.*	....
1904	28,876	5,336	700	(*c*)1,204	1,348,185	21,064	731	841,108	212	$160
1905	24,655	5,000	1,050	1,045	1,217,652	13,460	458	497,470	2,690	1,710
1906	19,516	4,517	1,276	861	1,035,138	6,455	220	244,299	84	50
1907	(*d*)17,532	3,000	400	712	868,678	5,132	175	192,094	16,566	6,719
1908	(*d*)16,969	2,832	346	685	903,391	2,995	110	124,960	15,113	8,215
1909	16,217	4,188	810	704	941,233	6,803	231	266,243	15,968	8,203
1910	(*d*)18,536	3,382	500	763	1,054,991	1,923	65	91,077	667	381
1911	18,860	(*g*)2,396	....	732	989,254	291	10	13,995	471,944	251,386
1912	20,600	2,700	1,847	855	1,067,742	310	14	13,360	82,706	39,919
1913	15,396	(*h*)	4,285	670	774,054	1,140	39	43,574	171,653	75,361
1914	11,485	(*h*)	5,083	536	811,832	1,446	49	70,753	685,605	300,000
1915	14,000	(*h*)	7,033	716	1,768,225	3,370	115	225,509	421,884	282,852
1916	21,045	(*g*)8,504	383	1,018	3,643,800	8,880	302	670,475	424,396	515,919

(*a*) Reported by the California State Mining Bureau, except 1907–08–10–11. (*b*) Included in "Other States." (*c*) Estimated; the weight of the flask was changed from 76.5 lb. to 75 lb. within this year. (*d*) Figures collected by MINERAL INDUSTRY. (*f*) Computed at average price at New York. (*g*) With Nevada. (*h*) Included in other states.

From the above it will be noticed that the imports fell rapidly while exports increased. The latter part of 1915 found our markets bought up and the price of quicksilver began to soar. Foreign governments ceased buying although they sorely needed the metal. To break the price over 3000 flasks were dumped on the American market during the first quarter when our prices were highest and this was followed by an additional 1700 flasks during the second quarter. This operation brought the price of quicksilver down rapidly from $300 per flask to $80 and at this figure the foreign governments began slowly to buy back the metal, but saw to it that no exceptional demands were made at any one time and that the domestic market was never entirely depleted. Only sufficient buying was done to use up our production as it was placed on the market without showing any keen demand for quicksilver. In this manner the price of the metal was held at a nominal figure and foreign governments were able to buy up the market without running up the price again. This action was typical not only of quicksilver but of practically all war materials which this country exported to warring nations during the year.

RADIUM

By Robert M. Keeney

The market for radium during 1916 was not very active, but toward the close of the year, it appeared to be stronger. There was evidence of increasing use of radium in the practice of medicine, and a considerable increase in its use in luminous paints, for the manufacture of which several concerns were organized. The increased use of luminous paints was partly due to the large number of wrist watches being worn by European armies, on which an illuminated dial is desirable.

Production.—The production of radium in the United States in 1916 is estimated at 8 to 10 gm., a considerable part of which was produced by the National Radium Institute in Denver. The coöperative arrangement of the Bureau of Mines with the National Radium Institute was completed during the year, by the production of 7 gm. of anhydrous radium bromide for the National Radium Institute, and in addition several grams were produced for the use of the Bureau of Mines and the Bureau of Standards in research work of the future. The plant of the institute in Denver was sold late in 1916 to the Pittsburgh Radium Co., which company took over the plant in January, 1917. This closed a very successful piece of coöperative work of the Bureau of Mines.

The Standard Chemical Co. did a large amount of development work on its claims in Colorado and is reported to have erected a new concentrator using wet concentration instead of dry concentration as was first attempted in a plant erected several years ago.

The Schlesinger Radium Co. of Denver enlarged its operations and force considerably. The manufacture of luminous paint was started by the Cold Light Manufacturing Co., a subsidiary of the Schlesinger Radium Co. Its products include door plates, street signs, push buttons, watch and clock dials and similar objects which are made luminous in the dark by use of radium paint.

The Chemical Products Co. of Denver began the production of radium on a small experimental scale late in 1916 and early in 1917 purchased carnotite claims near Meeker, Colo., with view to commercial production of radium.

Figures on the radium production of Bohemia[1] were published. There

[1] *Consular Repts.*, August, 1916.

was produced 25,720 lb. of pitchblende valued at $4.71 per lb. during the year 1915. From the government mine at Joachimsthal there was produced 2325 lb. of uranium compounds of an average value of $2.52 per lb. The government plant produced 1.754 gm. of radium products having a total value of $209,364.50. The radium production of 1915 represented an increase of 0.879 gm. as compared with the production of 1914, the value of which showed an increase of about $100,000.

Deposits.—The pitchblende deposit of Gilpin County, Colorado, is estimated by Richard Pearce,[1] the original discoverer, to have produced to date 10 tons of ore containing 60 per cent. U_3O_8 or 12,000 lb. U_3O_8. The deposit was first discovered in August, 1871. The pitchblende occurs in mica schist traversed by veins of feldspar and quartz enclosing magnetite, and the lode in the early days showed a width of 4 ft. at 60-ft. depth with 6 in. of solid pitchblende.

Metallurgy.—The extraction of radium from Colorado carnotite ore was investigated by H. Schlundt.[2] The experiments were made in 10-kg. portions ground to 20-mesh, which was gradually introduced into 18 liters of 78 per cent. sulphuric acid at 190° C. contained in a 50-liter cast-iron vessel, and then heated to 220° C. for at least 15 min. The calcium, barium and radium are held in solution as bisulphates. The liquid is then cooled to 130° C., and the insoluble silicates are filtered off on Filtros under a pressure of 5 to 10 cm. of mercury. The washing is done with two portions (5 liters each) of hot concentrated sulphuric acid. The acid filtrate is then poured into eight times its bulk of hot water, precipitating the radium and barium. If dilute barium chloride solution be added, the resulting precipitate will carry down 2 per cent. more of radium. After standing at least 3 days the solution is siphoned off and the sulphates washed on a stone filter with hot water containing a little barium chloride. If the residue of the filter is agitated several times with hot water and filtered, a deep blue solution is obtained from which a white precipitate gradually deposits, containing 3 to 9 per cent. of the original radium content of the ore. With low-grade ore the radium content was 235:1, with high-grade ore about 35:1.

An extensive investigation of the radium-uranium ratio in carnotite ores was made by S. C. Lind and C. F. Whittemore.[3] Except in a few instances carnotite has not been investigated as to the radium-uranium ratio. In so far as deviations from the normal radium-uranium ratio have been found for carnotite, these hitherto have been invariably low, and the impression seems to have become rather general, particularly abroad, that carnotite as a rule contains from a few per cent. to 30 per

[1] *Min. Sci. Press*, July 8, 1916, p. 44.
[2] *Jour. Phys. Chem.*, **20**, 485.
[3] U. S. Bur. Mines, *Tech. Paper* 88.

cent. less radium than would correspond to the uranium-content. It was therefore an important matter to have accurate determinations on a large number of carnotite samples.

The determination of the ratio in carnotites has also practical value because of the increasing importance of carnotite as the largest known source of radium. The practice is to buy and sell these ores on the basis of their percentage of uranium oxide, U_3O_8. Sometimes European buyers have insisted on making allowance for the supposed deficiency in radium.

The investigation of Lind and Whittemore on samples of carnotite representing large quantities of ore show a radium-uranium ratio identical with that of pitchblende (3.33×10^{-7}). This ratio is also in accord with the value calculated from radiation data. Samples from small quantities of ore tend to exhibit abnormal ratio, the results being both low and high. The most plausible explanation for these abnormal ratios seems to be that of transposition of radium within the ore bed, producing local ratios which are equalized in large samples.

Uses.—It was reported[1] that the Ingersoll Watch Co. was negotiating for the purchase of enough radium in southern Colorado and Utah to make 1,000,000 radium-illuminated watch dials. It was expected that during the coming year this company would put 1,000,000 watches on the market with illuminated faces. It was estimated that the life of the luminosity of radium for this purpose was 4000 years.

The British Admiralty specification[2] for radium luminous paint is 0.4 mg. of radium bromide per gram of zinc sulphide. The paint is also made with half that proportion of radium. The radium when mixed with zinc sulphide, exerts continuous excitation on the sulphide and eventually exhausts it. At the end of a year it is said to be probable that the paint made to the Admiralty specifications would have only half its original luminosity. The more radium the paint contains the shorter will be the life of the zinc sulphide. The act of mixing the paint exhausts the zinc sulphide somewhat, and it requires time for the radium to excite it to further action. A palette knife must not be used for mixing the paint or the crystalline structure of the zinc sulphide will be destroyed with a corresponding loss of illuminating power. Other substances than radium are used in paint, mesothorium more frequently. Ionium would be an ideal substance, but it is not obtainable in a pure state.

[1] *Salt Lake Min. Rev.*, Nov. 15, 1916.
[2] *Eng. Min. Jour.*, Nov. 11, 1916, p. 878.

SELENIUM AND TELLURIUM

There was apparently no production of selenium during 1916. The copper refineries, which are the only producers, had ample stocks on hand to satisfy the demand, which continues to be small. Sales, however, appear to have been about as large as in previous years. Sales are now made directly from producers to consumers. A few small lots were exported.

The United States production of selenium in 1914 amounted to 22,867 lb., valued at $34,277; in 1913, 29,097 lb., valued at $46,900.[1] More recent statistics are not available.

Under the conditions, price quotations are merely nominal. The quotations in the *Engineering and Mining Journal* remained stationary throughout the year, at from $2.50 to $5.00 per lb., depending on the size of the order. Actual sales, however, as made direct by producers, are estimated to have averaged at $1.50 to $2.50 per lb. The lower figure would represent prices for the larger orders placed by the glass-makers, usually for monthly delivery. The high price is due entirely to cost of production, as the refining of electrolytic copper slimes offers potentially a large supply as a by-product.

Research work on the use of selenium continues, and glass makers are known to be experimenting on the use of the salts, especially sodium selenite, in place of the metal.

Commercially selenium is sold in the granular form. Different lots vary considerably in analysis; the following would represent a good grade: Se, 99.0 per cent.; non-volatile matter, 0.4; Te, 0.2; Fe, 0.25; Cu, 0.05; S, 0.1; As, 0.15; Sb, 0.1.

There is no market for tellurium and consequently no production. Small quantities have been produced in the past in connection with selenium, the source being the same. Electrolytic lead slimes also form a source, in general containing much larger amounts of tellurium than selenium, while in copper refining the reverse is ordinarily true. Tellurium has been used in the glass industry and in medicine, but there have been practically no sales recently. Some of the refining companies have it in stock and quote it at prices slightly higher than selenium.

[1] U. S. Geol. Surv.

SODIUM AND SODIUM SALTS

By Samuel H. Salisbury, Jr.

Nitrate of Soda

The reports of the nitrate industry show that the course of the market has been governed by extrinsic factors.

As regards prospects, there does not appear to be much likelihood of a cessation of the demand for explosive purposes for some months to come, and so long as the demand continues, with an accompanying scarcity of freights, we can not reasonably expect to see lower prices. On the other hand, there are signs of a visible weakening of freights in certain directions, which weakness might extend to the nitrate districts. Importers can not be expected to run the enormous risk attached to present values for a position so far ahead as next spring unless they have some guarantee that their purchases will not be overlapped by Government purchases.

The principal features have been the continued demand for refined quality for explosive purposes (which has been considerably greater than generally anticipated), and the very large shipments to the United States and other countries outside of Europe. As regards the latter, however, the excess over the normal is also probably almost entirely due to the demand for explosives. The demand for agricultural purposes is understood to have been somewhat disappointing, due to a variety of causes, but probably principally on account of the difficulty of getting supplies when required and the necessarily high price through excessive freights. Taking the shipments for the year, May, 1915 to April, 1916, and making allowances for losses and loss in weight, the consumption in the United States and other countries for the year ending June 30, 1916, reached about 1,145,000 tons, as compared with 544,000 tons for the year ending June 30, 1915, and 645,000 tons for the year ending June 30, 1914. The floating quantity for Europe (including Russia) and Egypt at June 30, 1916, is estimated at about 333,000 tons, of which about 94,000 tons are still left remaining in German vessels held up in neutral ports. The Panama Canal was re-opened about the middle of April this year. According to the production lists 61 oficinas out of a total of 170 were producing in July of last year, but between then and

March of this year several re-opened and three new oficinas started, and altogether 117 were producing in March. In April of this year 112 oficinas were working, but out of the total of 173 oficinas 31 have not produced for about 3 years. Since the month of October, 1915, the production has averaged over 5¼ millions of quintals monthly; but, in spite of this, no progress seems to have been made in the suggested negotiations for restriction. Fortunately, however, heavier shipments than anticipated have to some extent counteracted against this heavy production unduly weighing on the market, but the effect seems certain to be felt sooner or later unless the present rate falls off more into line with consumption. The stocks in Chile have increased by about 300,000 tons since Oct. 1, 1915. The cost of production has shown a tendency to advance, owing chiefly to the increased cost of fuel and other necessities, but present f.o.b. prices should leave a fairly remunerative return to the better placed oficinas.

Reports from the Coast indicate that the shortage of shipping on the Pacific Coasts is causing a critical position in the industry. Large quantities of finished material are being stored by the companies which they cannot ship, and it is feared that production may have to be stopped. The producers are very reluctant to do this owing to the difficulty of recovering the labor once it is scattered. Coal is very scarce and exceedingly expensive.

During the past 6 months f.o.b. prices in Chile have steadily advanced to the extent of 30s. to 40s. per ton. In July the quotation was about 7s. 2d. per quintal for ordinary quality and 7s. 9d. per quintal for refined quality, both for this and next year's shipment in monthly strings. To-day, the quotations are 9s. 3d. and 9s. 6d. per quintal for ordinary and refined respectively, for shipment January to June, or the whole year at 9s. and 9s. 3d. respectively. The fact that even 1918 has shared in the business done at 8s. 3d. ordinary and 8s. 6d. for refined per quintal is strong evidence that, in some quarters at least, a hopeful view is taken of the industry when, presumably, war will be no more. We have no valid reason for condemning such a policy, but it might, perhaps, be just as well to exercise caution in the matter of far forward purchases, for who knows what new features in the industry the necessities of war may have brought about. It is tolerably certain that, even if no new discovery has been made, there will be a great deal of machinery for the manufacture of synthetic nitrate in Germany which may become, on the basis of its new capitalization, a formidable competitor, for a time, to the Chilean article. Perhaps, however, the prices now obtaining for 1917 are almost more dangerous from a purchaser's point of view (apart from Government purchases), being relatively so much higher. German peace offers must tell upon the nerves of holders and producers when prices rise to giddy heights. So far as the first 6 months of the year are concerned, we think holders have little to fear unless they have failed to secure their freight, but afterwards there might be more danger, having in view the latest move on the part of Germany to bring about negotiations for peace, which, to say the least of it, is peculiar from an enemy who considers himself the victor.

Consumption.—Consumption in the United Kingdom is an unknown quantity at present, but there can be little doubt that for some time past it has been greatly increasing for explosive purposes. In Continental ports the figures of consumption are unobtainable. America shows a considerable increase during the past 6 months. Figures for the 12 months are 1,105,000 tons, against 790,000. Stocks in Europe are an unknown quantity.

Production.—Twelve months ago some doubt existed as to the capacity of the market to cope with the increase which was taking place, but this fear has been set at rest during the last few months by the market's wonderful power of absorption. The question is, how long will it last? Should the present rate of production be the maximum, it is hardly likely that it will be found to be too much until the war is over, and that is about all one can say. The figures of production for the year are 63,300,000 quintals, against 38,123,000 the previous 12 months. Stocks in Chile are to-day just about what they were a year ago, being about 16,300,000 quintals, against 17,099,000.

Freights to-day are very nominal, quotations being about 140s. to 150s. per ton for sail or steam, but it is doubtful if one would be forthcoming at even 160.

The conclusion to be arrived at from these considerations is that nitrate in the immediate future cannot well be cheaper than it is to-day, and it may very easily be dearer; nevertheless, barring sulphate of ammonia, which may only be obtained in small doles, if, indeed, it can be had at all, it is probably cheaper than any other form of fertilizer obtainable. The pity is that supplies are so slender.

Mr. Thomson Aikman, Jr., in his annual report, says that the usual figures of deliveries, etc., can not be compiled, but the following table is a summary of the position for the past 4 years as far as it is possible to show.

It remains impossible to compile any figures of the European deliveries, or to forecast the probable supplies for the coming season, but as the consumption is principally for purposes other than agricultural, statistics are relatively unimportant, and, in fact, practically valueless. The floating quantity for Europe (including Russia) and Egypt at Dec. 31

is, however, estimated at about 470,000 tons, of which about 63,000 tons are still left remaining in German vessels held up in neutral ports.

	1913, tons.	1914, tons.	1915, tons.	1916, tons.
Exports to Europe and Egypt	1,996,000	1,218,000	1,059,000	1,603,000‖
Exports to United States, etc	700,000	600,000	933,000	1,296,000
Deliveries in Europe and Egypt	1,813,000	‡	‡	‡
Deliveries in United States, etc. (on basis of shipments 2 months previous)	695,000	600,000§	869,000	1,225,000
Visible supply for Europe and Egypt at Dec. 31	1,098,000	‡	‡	‡
Visible supply for United States, etc. (on basis of 2 months' shipments), at Dec. 31	89,000	69,000	127,000	187,000
Production in Chile, Jan./June	1,363,000	1,455,000	575,000	1,460,000
Production in Chile, July/Dec	1,367,000	967,000	1,153,000	1,402,000*
Average spot price in Europe per cwt. cost and freight terms	10/3	‡	‡	‡
Stocks in Chile at Dec. 31, estimated at	495,000	1,086,000	796,000	734,000†

* The production in December is taken as 236,000 tons.
† This figure allows for no oficina consumption or "merma" since the last official stocktaking at June 30, 1916.
‡ Figures not available owing to the European war.
§ After allowing for vessels lost on the voyage.
‖ Including Russia (Archangel and Vladivostok).

The market has been a difficult one to judge at any period of the year, and will almost certainly remain so during the war, but the outstanding feature has been the fact that shipments have equalled and even slightly exceeded production, in spite of the difficulty of securing tonnage. The total production for the 12 months has been about 63,200,000 quintals, against 38,200,000 quintals last year, and 53,500,000 quintals in 1914, of which about 32,200,000 quintals was produced January to June and 31,000,000 quintals July to December, 1916, against 12,700,000 and 25,500,000 quintals in 1915, and 32,100,000 and 21,-400,000 quintals respectively in 1914. Shipments during the past year to all parts have been about 64,000,000 quintals, against 44,000,000 quintals in 1915 and 40,100,000 quintals in 1914. Both the production and shipment figures for 1916 constitute a record for the nitrate trade. It is quite impossible under present circumstances to ascertain the actual consumption, although there appears to be no doubt that it has been large, but it would be very unwise to assume that shipments mean consumption, as there are no means at present of ascertaining to what extent stocks are being accumulated either in Europe or the United States. According to the production lists 116 oficinas out of a total of 172 were producing in January last, but these fell to 108 in September and October out of a total of 173. One new oficina opened in February, but only worked slightly for 2 months, and another of the older oficinas, which had not worked for nearly 10 years, re-opened with a new maquina in June. Since the month of August some of the German oficinas have closed down, but there are still believed to be working oficinas equal to about 50 per cent. of their productive capacity (about 9,000,000 quintals annually), and it is even reported that one of their oficinas, producing about 130,000 quintals monthly, which closed in September, is to reopen in January. Fears entertained at this time last year as to probable over-production have been falsified by actual events, more particularly by unexpectedly large shipments, but under war conditions it is more than usually difficult to form any opinion of the future, and the change to peace conditions, which must come some day, will doubtless prove equally embarrassing to those in the trade who must come to some decision, be it to buy or to sell. The cost of production is understood to have gone up considerably, due to higher prices for practically every commodity and the rise in Chilean exchange.[1]

NITRATE OF SODA STATISTICS (*a*)
(In tons of 2240 lb.)

Year.	Shipments from South America.	Consumed in Europe.	Consumed in United States.	Consumed in World.	Stocks in Europe.	Visible Supply at Close of Year.
1903	1,435,000	1,127,000	265,000	1,412,000	155,000	654,000
1904	1,476,000	1,131,000	275,000	1,447,000	162,000	672,000
1905	1,623,000	1,190,000	308,000	1,547,000	183,000	674,000
1906	1,700,000	1,243,000	355,000	1,636,000	190,000	733,000
1907	1,626,000	1,252,000	350,000	1,658,000	202,000	695,000
1908	2,017,000	1,378,000	309,000	1,732,000	402,000	928,000
1909	2,100,000	1,465,000	407,000	1,938,000	337,000	999,000
1910	2,300,000	1,651,000	501,000	2,241,000	310,000	969,000
1911	2,412,000	1,696,000	550,000	2,355,000	479,000	1,058,000
1912	2,478,000	1,908,000	481,000	2,508,000	310,000	1,004,000
1913(*b*)	2,739,530	(*c*)2,008,010	(*c*) 630,698	....	380,419	1,772,161
1914(*b*)	1,847,586	(*c*)1,198,367	(*c*) 540,143	....	....	1,087,910
1915(*b*)	2,031,014	(*c*) 999,739	(*c*) 850,978	....	....	789,700
1916(*b*)	2,991,786	(*c*)1,609,381	(*c*)1,226,816	....	....	718,315

(*a*) Statistics of W. Montgomery & Co., London. (*b*) Metric tons. Statistics of the International Institute of Agriculture, Rome. (*c*) Consignments from Chile.

Origin of Nitrate[2]

Theories advanced by investigators to account for the origin of sodium nitrate in Chile were reviewed by Lester W. Strauss, following discussions of this problem in a series of papers published some years earlier in the Boletín de la Sociedad de Minería de Chile. These theories include (*a*) the action of static electricity liberating oxides of nitrogen, forming nitric acid in contact with the moisture of the air; (*b*) accumulation of nitrates in soil through the action of certain microörganisms; (*c*) decomposition of seaweed during an earlier marine epoch of the inter-Andean valley; (*d*) oxidation of nitrogen in vegetal matter in the soil, a calcium nitrate being first formed that, reacting with sodium chloride, would produce sodium nitrate, setting calcium chloride free; (*e*) æolian

[1] *Min. Jour.*, July 8, 1916; Jan. 13, 1917.
[2] Courtenay De Kalb, *Min. Sci. Press*, May 6, 1916.

deposits of guano dust, reacting with the soil constituents; (*f*) nitrogen-bearing volcanic waters. The outcome of the discussion, as Mr. Strauss says, is to leave the ultimate source of the nitrogen an unsolved problem.

The physical conditions in Chile consist of a coastal range about 5000 ft. high, between which and the high wall of the Andes lies an elevated plateau, sloping from the Andes toward the Coast range. The region is practically free from rains. It is recognized that a season of heavy precipitation would leach and ruin a great part of the nitrate field. Mist and fog, however, are of nightly occurrence during the winter months, and it is observed that some connection exists between these mists and the nitrate deposits. Whether this is an accidental or a genetic relationship is still a moot point. It should be noted that enough rain falls to produce, in the course of centuries, a downward migration of any salts formed along the higher slopes, but not enough to leach the lower soils. The tendency would thus be gradually to enrich the deposits along the western or lower side of the plateau or pampa.

A well-known occurrence of nitrates near Rodeo, in southwestern New Mexico, offers a hint of another probable mode of origin for the Chilean deposits. If the rainfall at Rodeo were less than 1 in. per annum, and were confined chiefly to precipitation upon the mountain ranges bounding the Rodeo valley, it is practically certain that commercial deposits of nitrate would exist in this region. The rainfall is above 5 in., however, and the result is a valley possessing soils of extraordinary nitrogen content, famous for the production of beans by dry-farming.

The nitrate occurs as an incrustation upon the faces of the cliffs of tuff. It is more abundant where the rock has been recessed by æolian wear, or protected by overhanging cornices of the sculptured surface, but it is present in some degree wherever the tuff is exposed. It forms in the parting-seams of the rock, layer after layer being found to a depth of many inches. In places the enriched seams extend to a depth of several feet. The highest concentrations do not exceed 6 per cent. of sodium and potassium nitrate, and for the most part the outer shell will not yield over 1.5 per cent.

In the "washes" along the drainage-line leading from the Peloncillo range into the valley the detritus shows cemented zones gray with salt that generally carries from 1 to 2.5 per cent. of nitrate. Thus the migration of the salt toward the valley is conspicuous.

Very noticeable is the fact that where the tuff beds with their lava-caps have been faulted into a vertical position the amount of nitrate formed on the surface of the tuff is insignificant. The richer incrustations occur where the beds of tuff dip slightly toward the valley. It is also interesting to observe that the lava-capping possesses a rudely columnar structure, so that the precipitation to a large extent finds its way through the jointure into the underlying tuffs, which consequently are always moist at a depth of a few inches from the surface. Where the tuff forms the crest of the mountain no such phenomenon is seen, the rocks being peculiarly free from moisture.

The evidence is abundant that the nitrate is formed in the tuff, and is exuded toward the surface by seepage, which is mainly capillary.

The alteration of the tuff has been extreme, so that fresh specimens are difficult to obtain. Kaolinization has gone forward, with the formation of many hydrous aluminium silicates. Also the amount of magnetite in the altered tuff is most noteworthy, which may be connected with the series of reactions resulting in the generation of the nitrate.

Tuffs represent a product of volcanic outburst of explosive violence. At Mt. Peleé the inflammable gases in the *nueé ardent* were held in the ash-cloud, which as a whole possessed sufficient weight, despite its high temperature, to roll down to the sea, the gases lighter than air being held in this mantle of lapilli, and prevented by interference of particles from diffusing at once into the atmosphere. It would seem not improbable that extraordinary outbursts of lapilli, producing widely extended deposits of tuffs, must carry down large quantities of gases, both "entrained," to borrow a term from the steam engineer, and perhaps also occluded in the particles themselves. The latter as shown by M. Le Brun would be held tenaciously until liberated by alteration of the mineral constituents of the rock. In either case the gases would be evolved slowly, though long periods of time might be required for thick and deeply buried tuffs to part with their primary gas-content. Where hydrogen constituted part of the occluded gas the conditions would favor the direct formation of NH_3 in contact with the nitrogen of the air. Also, nitrogen and hydrogen in the volcanic emanation might form ammonia in the tuff itself, which would oxidize to nitric acid either by contact with dissolved oxygen in later infiltrating waters, or by being brought by seepage into contact with the oxygen of the air.

Finally, to revert to a possible rôle of magnetite in the genesis of nitrates, attention may be called to the production of this compound from the ferrous iron in decomposing silicates, in accordance with the following reversible reaction:

$$3FeO + H_2O = Fe_3O_4 + 2H$$

This reaction is uninfluenced by changes of pressure, the direction of the reaction being determined by variations of temperature. The production of Fe_3O_4 being strongly exothermic, the reaction would soon be halted. Lowering of the temperature favors the formation of the magnetite. Nascent hydrogen, evolved in this reaction, would unite directly with nitrogen, present from dissolved air in infiltrating water, or as primary gas-content:

$$3H_2 + N_2 = 2NH_3$$

Oxygen, similarly present in solution, would yield:

$$2NH_3 + 4O_2 = 2HNO_3 + 2H_2O$$

Free alkali, present from processes of alteration in the rock would then produce:

$$2HNO_3 + \left(\begin{matrix}K_2O \text{ or}\\ Na_2O\end{matrix}\right) = 2\left(\begin{matrix}KNO_3 \text{ or}\\ NaNO_3\end{matrix}\right) + H_2O$$

A well-known German process for the commercial fixation of nitrogen, developed within the last few years, depends upon the direct combination of nascent hydrogen with nitrogen to form ammonia.

Nitrate Industry in Chile.[1]—As the attention of this country is being drawn very markedly to the value of nitrate of soda, both as a fertilizer and for other less peaceful purposes, and as the so-called exhaustion of the deposits in Chile, due in 1921, according to the "authorities," has been indefinitely postponed, it is very opportune to describe for the American readers interested in this particular product how nitrate of soda is obtained from the crude deposits and, further, to indicate how American progress in other directions and industries is being used to attempt the modernization of the methods in use in Chile, and to reorganize completely the means of procuring the refining of so useful a product. It would perhaps be as well officially to refute once and for all the statement so widely circulated in this country and in Europe that the nitrate deposits in Chile are very rapidly becoming exhausted.

The official report recorded below is that of Mr. Francisco J. Castillo (the inspector general of the nitrate deposits for the Chilean Government), which was issued in November, 1913, by the Chilean Nitrate Committee of London, England, under the auspices of the Chilean Embassy in that country.

"According to the latest official report presented to the Chilean Government by Mr. Francisco J. Castillo, the inspector general of the nitrate deposits, the zone of nitrate-bearing grounds comprises 200,000 sq. km., of which so far only 5811 sq. km., that is to say, less than 3 per cent., are examined and their contents ascertained by excavation and test holes. These 5811 sq. km. belong to existing companies and private firms, and in part are still in the hands of the Chilean Government. The calculated contents of this 5811 sq. km. are 290,300,000 tons of nitrate of soda, of which up to the present 45,000,000 tons (1912) have been extracted and exported,

[1] I. Berkwood Hobsbawn, *Met. Chem. Eng.*, Mar. 1, 1917.

leaving in the examined part of the area 245,300,000 tons of nitrate of soda, equal at the present rate of production to a supply for a further hundred years. As the unexplored part is some thirty-four times larger than the explored grounds, it is safe to estimate that it contains altogether at least an equal quantity of nitrate of soda, and consequently the nitrate zone in Chile can certainly provide nitrate of soda for another 200 years at the present rate of production.

"The quantity of nitrate of soda in the examined grounds is subdivided as follows:

In the Province of Tarapaca there remains	35,000,000 tons.
In the Tocopilla district there remains	28,000,000 tons.
In the Antofagasta (central district) there remains	32,000,000 tons.
In the Antofagasta (Aguas Blancas) there remains	49,000,000 tons.
In Chanaral and Copiapo there remains	8,300,000 tons.
A total of	245,300,000 tons.

"The inspector general of nitrate grounds in his report to the Chilean Government has arrived at these figures in the following way:

"In these examined grounds no raw material containing less than 11 per cent. nitrate of soda has been taken into consideration, nor grounds where the thickness of the layer of raw material is less than 1 ft., except in the case of raw material of at least 25 per cent. of nitrate of soda, where the thickness of 8 in. and above has been included.

"The superficial area of each portion of ground examined has been divided by the total number of test holes made in order to arrive at the area applicable to each test hole, and this consequently determines the total nitrate-bearing area.

"From this theoretical quantity of pure nitrate of soda resulting from the above operations, a reduction of 40 per cent. has been made in order to provide for losses in extraction, manufacture, errors of calculation, etc. Of raw material of a lower grade vast quantities remain which have been excluded from these calculations because they can not be profitably extracted under the present system of work, but as improvements are being constantly made there is every reason to assume that even this low-grade material will be worked when the richer qualities are exhausted."

These statements, therefore, conclusively show that there is no fear of the Chilean nitrate deposits being exhausted for 200 years on the present basis of output and present efficiency of plant.

Taking into consideration that during the last 4 years an enormous impetus has been given to development work in Chile, through one cause or another, and that many workers are engaged in attempting to apply the principles found successful in industries in other countries, it will be agreed that some measure of success attending these developments would not only increase the estimated 200 years in proportion to the increased efficiency which these new processes would give, but would also bring into consideration the material of less than 11 per cent., which at present is not included, by making it amenable to treatment.

The methods of refining nitrate of soda have been variously referred to as crude and primitive, but whereas these terms might well be applied to the actual methods of lixiviation and mining, the mechanical means for carrying out such do not come under these headings; in fact, were it not for the development of the mechanical side of the operations, it is very doubtful whether the industry could have been carried on to any profitable extent with the lower-grade material now in use.

In modern works the handling of the raw material and the generation of power for that purpose and for the disposal of the refuse has been developed on very modern lines. The methods of treatment of the raw material, however, do not yield a high efficiency for various reasons, and it is because of this low efficiency in the works that methods of mining of the raw material are very much restricted; in fact, take the average efficiency of the process as 50 per cent., and the refuse over all, accounting for 10 per cent. nitrate, the minimum contents of nitrate in the raw material can not, except in special instances, be less than 20 per cent. Twenty to 22 per cent. is the general average of the material sent to the works for refining, and in order to gain this average ley of material from the grounds it is necessary to resort to hand-selection, such selection to a large extent depending upon the personal experience of the miner controlled by the general analysis performed in the factory. In this way the mining is costly and the percentage of nitrate taken out as raw material, out of the total of the deposits, comparatively low.

Some types of stony raw material with 10 per cent. nitrate content may yield up all their nitrate to the attacking solutions, while other varieties of 15 per cent. may only yield 4 per cent., or even nothing.

What is aimed at in the mining of nitrate-bearing raw materials is to get an average material as high in ley as possible, which will prove most amenable to the process of refining, yielding up to the solutions used for its lixiviation sufficiently high a proportion of its nitrate content while not causing too high a production of insoluble fines in the leaching tanks. This can only be attained by selection of material based on an extensive use of the personal equation.

It will be seen from this that so long as the present methods of refining are used, so long will the development of the mining of nitrate of soda on modern lines be delayed, and as a corollary so long will restrictions be placed upon the quantity of material which can be extracted from the grounds themselves.

The actual methods of mining of this raw material need not be gone into in detail in an article of this nature, but it might be sufficient to indicate that with the restrictions which have been referred to above there is very little possibility of being able to operate to advantage the mechanical methods of mining, which would so reduce costs of operation as has been found in other mining industries. It is even doubtful as to whether the modern methods of mining could ever be easily adopted in the Chilean fields in their entirety, assuming it were possible to treat an average grade of material of about 5 per cent. The main reason for this is the irregularity of the deposits, both as regards distribution and thickness.

The miners work on piecework, being paid a price agreed on for every cartload of suitable material passed to the works. The hand-selected material is loaded into carts holding from 2¼ to 2½ short tons, the lumps weighing anything from 25 to 50 lb. It is kept as free from dust and barren overburden as possible, although a fair proportion of useless "smalls" is often brought in with the selected material. An average analysis of 22 per cent. caliche used in the process might be taken as below:

	Per Cent.
Nitrate of soda	22
Chloride of soda	20
Sulphate of soda	4
Insoluble matter	54
	100

The nitrate may be present as nitrate of soda, potash, lime, magnesia, though all of these bases are not necessarily always present. Chlorine is also present allied with traces of these other bases, and sulphates of lime and magnesia are also present in varying quantities.

China.[1]—An American who has recently been employed with the engineering department of the Standard Oil Co. states that he is in touch with certain Chinese who have secured a monopoly for the collection of saltpeter in three provinces. Interest appears to have been originally aroused in the subject by rumors of the probability of a large Russian demand; but this does not seem to amount to anything at present, and the attention of the promoters has been turned to a possible American market.

The price originally quoted was $33 Mexican per picul of 133⅓ lb., and at the then rate of exchange the American representative calculated this meant the possibility of delivery f.o.b. treaty port (probably Tientsin) at a figure that would compete with the rate then ruling in New York. However, the gold value of silver has since appreciated somewhat—a factor which, of course, ordinarily militates against export trade—and further investigation would probably be necessary before such a price could be accepted.

The promoters claim to be able to deliver at 3 weeks' notice quantities of 400 to 500 tons.

United States.[2]—Nitrate deposits in many parts of this country have been examined during the last 2 years by the U. S. Geological Survey. The importance of finding a natural supply of nitrates within our own

[1] *Comm. Rept.*, Nov. 8, 1916.
[2] *Min. Sci. Press*, Dec. 30, 1916.

borders, which might serve our needs in case of war, has given incentive to this work, and has directed widespread public attention to the subject.

Prospectors in many places have raised great hopes by finding good surface-showings of these salts, but investigation has seemed to force the acceptance of a general adverse judgment as to their value—a judgment that has been adopted with the greatest reluctance by all concerned. Incidentally, advantage seems to have been taken of the situation to promote certain share-selling enterprises, even after the evidence as to the worthlessness of the deposits became sufficient to satisfy any competent judge, so that one is forced to question either the good faith of the promoters or their practical judgment. As a result of careful study of these deposits, and particularly of evidence gathered on recent visits to prospects in different parts of the country, Hoyt S. Gale, a geologist of the Survey, has submitted the following general summary, which is commended to the consideration of those tempted to invest their money in such enterprises.

Fine specimens of practically pure nitrate of soda and nitrate of potash (saltpeter) have been found in many parts of the country, and careful investigation of specimens and localities seems to warrant some definite conclusions as to the practical value of these deposits, especially to those who are invited to spend their money in investigations like those the Survey has already made. The nitrate salts occur as crusts or films on the faces of ledges; as seams—most of them thin, though some are fairly thick—in crevices of shattered rock; and as deposits filling spaces in porous rocks at and near the surface or extending to a depth of several feet. They are naturally preserved in recesses in the rock-ledges, where they are sheltered from the dissolving action of rain, snow-water, or even mist. They are found in lava-ledges, in beds of volcanic tuff or ash, and in limestone and sandstone. Their existence or preservation is apparently dependent rather on the shattered or porous nature of the rock than on its kind or composition. These deposits, which have been referred to as cave or ledge deposits, are of essentially the same type wherever found, although they vary considerably in details of occurrence. The incrustations are found not only on the faces and fractures of ledges of solid rock, but some fo them form layers of cementing constituents in the loose soil and rock-breccia at the bases of cliffs, or lie in places protected from the weather. Some samples obtained from both these sources are rich in nitrate salts, and analyses of such materials will bear little significant relation to the actual character or content of the mass of the rock of which the ledge is formed. It appears that the deposits are surficial—that is, they do not extend far into the mass of the rock—and the nitrate salt found is insignificant in amount. Nitrates are found in unusually large quantities in some soils and in some clay hills, particularly in southern California. These deposits have been examined by many persons and the general conclusion reached has been unfavorable to the idea of their practical utilization. The nitrate content, although unusually large as compared with the content of ordinary soils, probably does not average over 1 or 2 per cent. of the soil or clay, and it is doubtful whether the material could be worked commercially.

IMPORTS OF SODIUM SALTS (*a*)
(In tons of 2000 lb.)

	1912.		1913.		1914.		1915.		1916.	
	Tons.	Value.	Tons.	Value.	Tons.	Value.	Tons.	Value.	Tons.	Value.
Arsenate	178.3	$11,195	634.0	$55,941	114.1	$8,267	42.9	$2,188	18	$3,341
Ash	1452.7	33,459	1550.4	35,461	1,114.5	28,102	1,063.7	29,022	508	29,134
Bicarbonate	55.0	3,193	40.3	2,238	44.4	2,324	49.7	2,584	28	98,834
Bichromate and chromate	......	....	......	3	5.5	542	....	....	3	3,630
Caustic	465.3	28,937	335.7	25,364	332.7	23,914	222.1	19,318	77	24,606
Carbonate (crystal)	177.3	5,616	84.6	2,928	103.7	309	72.2	2,748	31	1,316
Chlorate	......	22	......	10	0.2	84	....	6	....	....
Chloride (salt)	145,041	379,539	125,428	356,911	16,987.5	456,426	1,290.0	386,564	121,967	342,588
Hyposulphite	4.3	277	3.6	228	463.1	128,828	927.6	268,693	2	1,261
Nitrate	481,786	15,427,904	656,672	20,713,375	620,533.2	17,926,165	644,415	16,240,510	1,365,962	38,131,364
Nitrite	487.3	47,399	634.8	57,595	922.2	76,813	848.8	74,267	1,815	255,755
Phosphate	......	....	......	14	682.4	24,975	247.6	7,665	1	462
Prussiate	823.2	90,654	943.7	118,475	1,147.9	171,831	765.0	120,477	199	175,089
Sal soda	126.8	2,020	64.0	1,010	81.8	1,274	52.4	606	11	121
Salt cake	659	8,394	189.1	4,771	31.4	618	211.7	3,566	333	9,534
Silicate	466.6	8,870	516.1	9,400	523.3	10,881	744.0	16,292	740	20,807
Sulphide	361.5	10,456	475.8	12,360	1,265.0	36,383	631.7	18,228	93	7,432
Sulphite	177.1	4,860	13.6	400	191.3	5,627	82.8	4,316	34	1,272
Sulphate	......	....	336.3	5,685	455.1	7,475	59.4	1,113	1	33

(*a*) For fiscal years ending June 30.

Soda

Africa.[1]—A large deposit of raw crystalline soda at Lake Magadi, situated in the southern part of this protectorate, near the frontier of German East Africa, has attracted attention in recent years. This lake has an area of approximately 324 sq. miles and contains from 50,000,000 to 200,000,000 tons of sesquicarbonate of soda. On account of the existing soda springs in the lake, the supply is constantly being renewed, and it may therefore be said to be nearly inexhaustible. The raw material must be reduced to soda ash. Analysis of the product shows: soda crystals, 98.55 per cent.; salt, 0.20 per cent.; sulphate of soda, 0.10 per cent.; moisture and traces of impurities, 1.15 per cent.

About 5 years ago the Magadi Soda Co. (Ltd.), a British corporation, was formed to take over a 99-year lease of this deposit, with the company under the management of M. Samuel & Co., of London. In 1913

[1] *Comm. Rept.*, Mar. 17, 1917.

a branch railway line was constructed to connect the property with the Uganda Railway System, thus affording an outlet for shipments at the seaport of Kilindini.

In 1914 the company expected to ship about 80,000 tons and gradually to increase the annual output until it reached 200,000 tons. Just at the time their plans were beginning to materialize, however, the war put a stop to operations. It is believed that active operations will be resumed just as soon as ocean freight rates become normal, or the market price of the product advances to a point which will warrant the payment of the present high shipping charges. The company has been granted a very favorable railway rate from the mines to the seacoast, enabling it to place the product aboard ship at Kilindini for about $4 per long ton. The ocean rate from Mombasa to New York via Durban or Liverpool is now about $39 per long ton.

England.[1]—Attention has recently been called to a newly patented method for manufacturing a form of sodium carbonate, hitherto not produced on an industrial scale, and an improved method of making silicate of soda. The new processes are as follows:

Past attempts to produce a sodium carbonate containing 5 molecules of water have yielded a salt which would cake into bricklike hardness, even after having been ground into very fine powder. In the process in question, a mixture of 106 parts of 58 per cent. alkali and 90 parts of water is introduced into a Pfleiderer machine, which is kept in motion at a determined speed. As a result an absolutely stable carbonate, containing 5 molecules of water, is obtained in the form of a powder which shows no tendency to cake. It does not absorb moisture from the atmosphere, nor does it effloresce. For the manufacture of bleaching sodas containing sodium silicate, this powder is mixed with the required quantity of powdered silicate, made by the process described further on. The mixture never cakes, is always ready, and is easy to use. It serves admirably in the manufacture of scouring powders and soap powders, furnishing products which never cake. In fact, for all purposes requiring the use of soda the new product gives excellent results. It is not so caustic as ordinary 58 per cent. alkali. It dissolves more readily than other forms of soda, is easily handled, and never cakes.

By the newly patented method silicate of soda is made in a form that is much more marketable, and more easily used than is the case with the current commercial forms of water glass. There is a considerable saving in freight, packages, and handling. The cost of manufacture is much lower than by other methods now in use and the plant required is exceedingly simple and cheap, occupying a very small space.

[1] *Comm. Rept.*, Sept. 23, 1916.

The process of manufacture is much similar to that employed in making the sodium carbonate described above. Silicate glass is introduced into a pulverizing machine of approved type together with a certain amount of water. This amount depends upon the strength of the silicate of soda desired. The revolution of the machine brings about a gradual pulverization and hydration of the silicate. After the operation has continued for some time, the contents of the machine, which resemble milk in appearance, undergo a special treatment causing solidification. This solid form of soluble silicate can be easily ground into powder. It can also be prepared in a liquid, or gelatinous condition. It is neutral and the solution can be concentrated to any required point. The solid silicate can be packed in crates or boxes. The freight upon such inexpensive packages is almost negligible. Among the advantages claimed for this new process over other methods now in current use are: lower cost of production, cheaper packages, easier handling, lower freightage, and a much greater facility of utilization.

Among the uses of sodium silicate, in which such an improved form of preparation offers distinct economy, are the following: the manufacture of concrete and artificial stone; of fire-clay; of grindstones and emery wheels; of acid-resisting cements for jointing, insulating purposes, and waterproofing walls; of fireproofing; of steam-pipe covering; of asbestos slates, uralite, etc.; in the textile trade as a sizing, bleaching, or fixing agent; as a very valuable detergent and scourer; for rendering fabrics incombustible; as a sizing material for paper; for water paints and enamels; for drain-pipe cements; as a detergent and filling agent in soaps; for preserving eggs.

Mexico.[1]—A factory for the production of bicarbonate of soda is to be established, under the supervision of the Department of Fomento, near Lake Texcoco in the Valley of Mexico. The waters of this lake will be evaporated for the production of the salt.

Sweden.[2]—There is great scarcity of soda in Sweden at present. Before the war the wholesale price was 6 crowns per 100 kilos ($0.729 per 100 lb.), then it went up to 12 crowns ($1.459 per 100 lb.), and now it has been raised to 36 crowns ($4.376 per 100 lb.). The prices of washing powder follow the prices of soda and are consequently very much higher than under normal conditions.

The glass works are greatly affected by the shortage in the supply of calcined soda, and three of them have been compelled to discharge a part of their working force on account of lack of this material. Some of the glass works have commenced to use Glauber's salt and potash.

[1] *Bull. Pan Amer. Union*, Feb. 1, 1917.
[2] *Comm. Rept.*, June 12, 1916.

The shortage is due to the inability of securing soda from England and Germany, the usual sources of supply. It is reported that the eight soda factories in Sweden have had to shut down.

It is intended to negotiate for supplies of soda ash from the United States, although the high prices and freight rates are serious obstacles. It is supposed that some soda can be obtained from Germany in the near future, although the German soda works, ordinarily manufacturing for export, are closed at present. At any rate, it is assumed that prices will continue to be high.

Russia.[1]—The soda industry of Russia did not need base ingredients from abroad, but with the German occupation of western territory it lost a market for about 20 per cent. of its production. In addition, the industrial activities of the several Governments within the range of operations of the army were curtailed to a considerable extent. Nevertheless the combined demand for sodium carbonate and caustic soda decreased only 12 per cent. during 1915; the use of caustic soda (sodium hydroxide) increased slightly. The consumption of these two products was as follows during 1913, 1914, and 1915: Sodium carbonate—5,973,000 poods (107,850 short tons) in 1913, 5,685,000 poods (102,660 tons) in 1914, and 4,578,000 poods (82,660 tons) in 1915; caustic soda—3,173,000 poods (57,290 tons) in 1913, 3,251,000 poods (58,700 tons) in 1914, and 3,279,000 poods (59,210 tons) in 1915. The average prices for caustic soda were as follows: 1913—2.46 rubles per pood; 1914—2.44 rubles per pood; 1915—2.64 rubles per pood. [At the normal rate of exchange the ruble is equivalent to $0.515; its present exchange value is about $0.21. The pood is equal to 36.1128 lb.; 1 short ton contains 55.382 poods.]

Salt

The operations of the Western Salt Co.[2] at the south end of San Diego Bay in southern California are typical of present-day practice in the refining of high-grade salt by solar evaporation.

The source of supply is the water of San Diego Bay, a long and narrow land-locked arm of the Pacific Ocean. The bay has a very narrow entrance situated at the extreme northern end, so that the water does not change completely with each ebb and flow of the tide. This condition, together with the facts that the inflow of fresh water is small and the evaporation high, tends to a natural concentration of the solids, so that the proportion in the water at the southerly end of the bay, where the plant is situated, is somewhat higher than in the ocean water.

[1] *Comm. Rept.*, Apr. 21, 1917.
[2] Leroy A. Palmer, *Met. Chem. Eng.*, **16,** 317–19.

Detailed analyses of the water of San Diego Bay are not available, but some samples run for sodium chloride have shown as high as 4 to 5 per cent. NaCl.

Two analyses of the ocean water gave the following results:

Substance.	Per Cent.	
$NaCl$	2.670	2.700
$MgCl_2$	0.322	0.360
$MgSO_4$	0.197	0.230
KCl	0.129	0.070
$CaSO_4$	0.163	0.140
$NaBr$	0.042	......
$CaCO_3$	0.017	0.003
$MgBr_2$	......	0.002
Na_2CO_3	0.014	......
Fe_2O_3	0.003	......
NaI (or MgI_2)	0.0024	......
Other solids	0.004	0.025

In the manufacture of salt by this process the amounts of evaporation and precipitation will, of course, play an important part, the former promoting and the latter retarding the crystallizing of the salt from the water. The site chosen for the location of the plant is such as to give a net annual evaporation of 50 in., a total evaporation of 60 in. against an average precipitation of 10.01 in.

This company was seriously damaged by the heavy floods of January, 1916, and has not yet gotten back to its former equipment or scale of operations. In the following description the practice as indicated by the number and area of the ponds is not strictly in accordance with present methods but pertains rather to those followed prior to the flood and which will closely approximate those to be used when damaged dikes can be repaired and other changes made.

The first step in the process is the admission of the bay water to the tide ponds. There are four tide ponds, having a total area of 250 acres, three of them equipped with 16-ft. and one with 8-ft. tide gates. The ponds are surrounded by a levee 10.5 ft. high and 3 miles long. The water is admitted at high tide, which reaches an average maximum of 7.4 ft. The density[1] of the bay water as admitted is 17° S. (4.4° Bé.). The water is retained in the tide ponds until the next high tide, 2 weeks, just preceding which it is transferred by pumping.

Pumping is by two centrifugal pumps, operating in parallel by direct connection to a 50-hp. motor. The combined capacity is 15,000 gal. per minute. Each pump has a 36-in. suction and a 24-in. discharge, the two discharge pipes uniting in one main 36-in. line. By this means the water is lifted 8 ft. to a sump, from which it flows to the high point of the secondary ponds, among which it is distributed by means of gates

[1] The figures for density given in this article, both in salometer degrees and in Baumé degrees, were supplied by the company. While the usual salometer scale gives directly the percentage of salt in solution, a different salometer scale is used, the idea being evidently to get a wider range of figures and permit greater accuracy.

between the ponds. These secondary ponds are nine in number and have a total area of 333 acres.

At the end of 2 weeks, time for another flow to the tide ponds, the water has reached a density of about 26° S. (6.77° Bé.), and is concentrated in the lower secondary ponds to make room in the upper ponds for another pump run.

Evaporation is continued further in the secondary ponds until a density of 36° S. (9.26° Bé.) is reached. The secondary ponds are sometimes referred to as the "lime ponds," as the calcium carbonate deposits from the brine and settles to the floor of the pond at about 30° S. (7.82° Bé.).

From the last of the secondary ponds the brine is run to the pickling pond, which has an area of 112 acres. Here evaporation is continued until the brine has a density of 100° S. (24.1° Bé.). Gypsum (calcium sulphate) commences to settle out at 55° S. (13.78° Bé.) and is practically all thrown down by the time the density reaches 100° S.

When this density is reached the brine is drained to the crystallizing pond of 51 acres, and at 106° S. (25.2° Bé.) the salt commences to deposit.

As stated, the net annual evaporation on San Diego Bay is approximately 50 in. The density of the water in the crystallizing ponds is such that 1 in. of salt is thrown down for each 6 to 7 in. of evaporation, so that the annual deposit of salt is from 7 to 8 in. As 1 acre-in. of salt weighs approximately 110 tons, this gives a crop of 770 to 880 tons per acre. It has been found that a depth of 6 to 8 in. allows of the most economical harvesting.

Evaporation is continued in the crystallizing ponds to a density of 130° S. (29.67° Bé.), and the brine then transferred to the bittern ponds. Up to 132° S. (30° Bé.) the sodium chloride will crystallize out pure with the exception of a small amount of magnesium chloride, but above 132° other salts will deposit, magnesium sulphate being the first to be thrown down.

When the brine is drawn off from the crystallizing ponds, the salt remains as an incrustation, showing typical isometric crystals characteristic of halite. Many of these crystals are large, an inch or more in diameter, and exhibit a beautiful rose pink color due to the presence of magnesium chloride.

Harvesting is usually commenced the latter part of August and continued until the latter part of November. It has been found that the most economical practice is to use the rather primitive method of hand-shovelling, as this prevents cutting too deeply and bringing up impurities with the salt.

The crystallized salt is shovelled to small two-way dump cars on 36-in. trucks, which can be shifted from time to time to keep them within easy reach of the shovellers. The train of cars is hauled out of the crystallizing pond by a gasoline locomotive and dumped to a shallow bin. The bin is V-shaped, 100 ft. long, 4 ft. wide, with sloping sides, and 4 ft. deep. It is provided with 31 rack-and-pinion gates in the bottom, operated from above by hand wheels, by means of which the salt is discharged through the bottom to a screw conveyor, which works it to a belt elevator.

The elevator raises the salt 10 ft. and dumps it to the washer, which is simply a box or trough 30 ft. long, 2 ft. wide and 4 ft. deep, with a screw conveyor in the bottom. The washing is accomplished by working the salt through this trough by means of the screw conveyor against a current of a density of 50° S. (12.5° Bé.), which is pumped from the pickling pond. The trough is kept full of the brine, which flows back to the pond after passing through. During the process the density of the wash water is increased to 100° S. by the salts which it dissolves. This wash water is raised from the pickling pond by a 3-in. centrifugal pump and delivered to a small pond near the washer, from which a 5-in. centrifugal raises it to the washer.

The screw from the washer delivers the salt to a bucket elevator running on an angle of 45° with a vertical lift of 50 ft. Near the boot of the elevator it receives a final brine washing by a drip from the pump line and as it is elevated it passes under two perforated pipes, which spray it with fresh water. This removes any dirt or mother liquor which may have escaped the previous washing and precipitates any gypsum which may have remained, so that the dried product analyzes 99.823 per cent. $NaCl$. The small amount of impurities which does remain consists of sulphates of calcium, magnesium and sodium and chlorides of calcium and magnesium.

The elevator described dumps the salt to a semicircular trough with bottom gates carried on a trestle. A screw works in this trough so that by opening the proper gate the salt may be discharged at any desired point to the stock piles.

The salt is thus stacked in piles 50 ft. high and allowed to dry in the air, by which process the moisture content is reduced to 1½ to 3 per cent. Under the platform supporting the stock piles are horizontal screw conveyors so that, as the salt is picked down by hand, it is carried along to the boot of a scraper elevator. This elevator runs at an angle of 45° and delivers to a short screw, which feeds a 4 by 12-ft. hexagonal trommel with a ⅜-in. wire screen.

Oversize and undersize of the trommel run to spouts and thence to

50-lb. sacks, which are automatically weighed, sewed and tossed to a short belt conveyor, by which they are delivered either to the shipping platform or boxcars. Elevating, sacking and weighing machinery are mounted on trucks on a 6-ft. track running parallel to the stock pile, so that they may always be convenient to that part of the pile which is being shipped.

The annual output of the plant is from 30,000 to 40,000 tons.

The bittern water, the drainings of the crystallizing pond, which is now going to waste, contains compounds from which valuable by-products could be obtained.

An analysis of this water shows total solids of 28.86 per cent., as follows:

$MgCl_2$	9.10
$MgSO_4$	5.60
NaCl	12.06
K, Br, etc.	2.10

Specific gravity = 1.2608. Weight per gallon = 10.51 lb.

The magnesium chloride is the most important constituent of the bittern water, forming as it does 31.5 per cent. of the total solids. Prior to the floods mentioned the Magnesium Products Co. operated a plant adjacent to the salt ponds and bought the bittern water on contract. Its principal products were magnesium chloride and magnesium sulphate (epsom salts). Unfortunately this plant was almost directly in line with the flood and was a total wreck. It has not been rebuilt and the Western Salt Co. is now desirous of making another contract of a similar nature by which this waste may be utilized.

PRODUCTION OF SALT IN THE UNITED STATES (*a*)
(In barrels of 280 lb.)

Year.	California.	Kansas.	Louisiana.	Michigan. (*c*)	Nevada.	New York. (*c*)	Ohio, W. Virginia, and Pa. (*b*)	Texas.	Utah.	Other States.	Total, Barrels.
1906	806,788	2,198,837	1,179,528	9,936,802	11,249	8,978,630	3,436,840	(*d*)	262,212	1,361,494	28,172,380
1907	626,693	2,667,459	1,157,621	10,786,630	6,459	9,657,543	4,007,390	(*d*)	345,557	464,143	29,719,495
1908	899,028	2,588,814	947,129	10,194,279	9,714	9,005,311	3,572,635	(*d*)	242,678	1,291,042	28,750,630
1909	886,564	2,769,849	(*d*)	9,966,744	16,107	9,880,618	3,835,267	(*d*)	246,935	2,505,562	30,107,646
1910	937,514	2,811,448	1,372,248	9,452,022	17,535	10,270,272	3,829,475	382,164	249,850	983,128	30,305,656
1911	1,086,163	2,159,859	(*d*)	10,320,074	12,856	10,082,656	4,485,886	385,200	272,420	2,391,710	31,196,824
1912	1,090,000	2,573,626	(*d*)	10,946,739	12,536	10,502,214	5,408,300	373,064	283,293	2,135,036	33,324,808
1913	1,082,993	2,698,079	(*d*)	11,528,800	8,971	10,819,521	5,424,056	355,529	330,443	2,189,913	34,438,305
1914	(*d*)	2,967,864	(*d*)	11,670,976	4,436	10,389,314	5,628,265	433,979	375,457	2,332,649	34,804,683
1915	1,048,457	3,765,164	(*d*)	12,588,788	6,929	11,217,471	6,112,482	444,978	394,850	2,652,377	38,231,496
1916	1,124.236	4,564,793	(*d*)	14,918,278	......	14,087,750	6,706,193	......	......	....	45,449,329

(*a*) Statistics of the U. S. Geological Survey except for New York since 1905, which are from report of the State Geologist. (*b*) The production of Pennsylvania since 1905 is included in "Other States." *c*) Includes brine used in manufacture of alkali. (*d*) Included in "Other States."

CONSUMPTION OF SALT IN THE UNITED STATES
(In tons of 2000 lb.)

Year.	Production.		Imports.		Exports.		Consumption.	
	Amount.	Value.	Amount.	Value.	Amount.	Value.	Amount.	Value.
1902........	3,338,892	$5,668,636	184,764	$647,554	5,094	$55,432	3,518,562	$6,260,758
1903........	2,655,532	5,286,988	165,981	495,948	12,750	95,570	2,808,763	5,687,366
1904........	3,084,200	6,021,222	166,140	467,754	13,964	113,625	3,236,376	6,375,351
1905........	3,635,257	6,095,922	161,159	492,189	34,238	239,223	3,762,178	6,348,888
1906........	3,944,133	6,658,350	170,505	502,583	33,988	274,627	4,080,650	6,886,306
1907........	4,160,729	7,439,551	153,435	452,227	30,802	232,895	4,283,362	7,658,883
1908........	4,024,345	7,486,894	156,609	440,484	26,627	202,338	4,154,327	7,725,040
1909........	4,215,070	8,343,831	158,487	447,983	40,158	269,273	4,333,397	8,522,541
1910........	4,242,792	7,900,344	142,549	388,015	49,013	320,926	4,336,328	7,967,433
1911........	4,365,756	8,345,692	137,759	378,083	48,873	335,285	4,454,642	8,397,490
1912........	4,665,473	9,402,772	136,391	361,664	62,410	418,525	4,739,454	9,345,911
1913........	4,821,368	10,123,129	150,601	416,375	70,289	515,194	4,901,680	10,024,310
1914........	4,872,656	10,271,358	130,752	385,752	82,295	586,055	4,921,113	10,071,055
1915........	5,352,409	11,747,686	123,576	366,475	80,474	613,850	5,395,511	11,500,311
1916........	6,632,906	13,645,947	121,467	342,588	91,513	628,966	6,393,040	13,359,569

Canada.[1]—The Canadian salt production is obtained from southern Ontario. The total sales in 1916 were 124,033 tons, valued at $668,627 (exclusive of the cost of packages). The 1915 sales were 119,900 tons, valued at $600,226.

In addition to the production of salt, brine is pumped for use in chemical works at Sandwich, Ontario, where caustic soda and bleaching powder are manufactured by the Canadian Salt Co.

The exports of salt in 1916 were 305,900 lb., valued at $2223. The total imports of salt were 151,208 tons, valued at $694,835, and included 34,035 tons of fine salt in bulk, valued at $111,130; 7679 tons of salt in packages, valued at $59,980 and 109,493 tons of salt imported from Great Britain for the use of fisheries, valued at $523,725. The total imports in 1915 were 137,486 tons, valued at $517,526.

Colombia.[2]—The Government of Colombia has contracted with Carlos Palacia for the establishment of a modern salt factory on one of the Tumaco Islands on or before the middle of the present year. The salt produced in this factory is to be offered for sale in the Departments of Narino, Cauca, and Valle at a price not exceeding the price of foreign salt in said departments.

China.[3]—The production of salt is controlled in all parts of China by the Government, although actually in the hands of private producers. There is only one producing center of salt of great importance in the Hankow consular district. That is Ying Cheng Hsien in Hupeh, producing an estimated quantity of 15,000 tons per annum. Ying Cheng lies north of the Siang River, bordering on a number of shallow lakes and waterways which provide transportation to the Siang River. It is about 25 miles west of the Peking-Hankow railway station of Siaokan.

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[2] *Bull. Pan Am. Union*, Jan., 1917.
[3] *Comm. Rept.*, July 25, 1916.

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SULPHUR, PYRITE AND SULPHURIC ACID

By Samuel H. Salisbury, Jr.

Sulphur

In the sulphur trade itself the war is working considerable modifications. Gradually the ingenious Frasch process has enabled the United States to gain upon the primitive Sicilian sulphur industry until, after practically equalling its output in 1914, it last year established a definite lead. In 1915 the total Italian production is stated at 364,260 metric tons, while that of the United States was in excess of 400,000 tons. The Union Sulphur Co. in Louisiana is estimated by the International Institute of Agriculture to have yielded 381,000 tons, while the Freeport mines in Texas appear to have produced between 20,000 and 30,000 tons. The plant there is only gradually coming into operation, and the output will, no doubt, be considerably enlarged this year. For the first 6 months of 1916 the Italian output further declined, showing a total of 150,634 tons. While the Sicilian industry has been operated under considerable difficulties through shortage of freight and the cutting off of important markets, the demand for sulphur has been such that one of the great bugbears of the situation, the long-standing accumulated stocks, have been very considerably reduced and that despite a considerable advance in prices by the Consorzio. The stocks, which at the end of 1914 stood at 369,001 metric tons and at the end of 1915 at 274,069 tons, had increased again at the end of June last year to 323,391 tons, from which they were reduced at the end of last June to 167,511 tons, a total far below what they have ever stood at in recent memory. This result has been mainly due to the great activity of shipment in 1916. France took 76,098 tons for the first 6 months of the year, as against 96,156 tons for the whole of 1915, the United Kingdom took 41,455 tons against 36,156 tons, Australia 23,154 tons against 330 tons, Russia 12,529 tons against 2791 tons, and Portugal 13,993 tons against 12,784 tons. These are the chief increases comprised in an export showing for the 6 months of 281,858 tons as against 359,806 tons for the whole of 1915. Since the war there has been an increasing call for sulphur for the manufacture of sulphuric acid, more especially from the United States, and this probably accounts for the main increase in the demand which has been shown. The only other considerable producer of sulphur previous to the war was Japan, the output from which in 1915 was 61,405 tons. The enterprise of the New Zealand Sulphur Co. which was preparing to work sulphur deposits on White Island, was, unfortunately, disturbed by an earthquake, which destroyed the plant and killed a certain number of the men at work.[1]

SULPHUR IMPORTS AND EXPORTS OF THE UNITED STATES
(In tons of 2240 lb.)

Kind.	1911.		1912.		1913.		1914.		1915.		1916.	
	Amt.	Value.	Amt.	Value.	Amt.	Value.	Amt.	Value.	Amt.	Value	Amt.	Value.
Imports:												
Crude	24,250	$436,725	26,885	$494,778	14,636	$278,056	22,810	$409,537	24,647	$405,990	21,289	$ 358,416
Flowers	3,891	83,491	1,310	39,129	5,899	115,574	621	17,214	647	23,146	425	18,408
Refined	986	24,906	1,665	40,933	1,234	29,091	1,800	47,568	988	30,335	455	15,020
Precipitated	68	8,643	66	9,137	350	17,690	105	14,161	85	12,987	66	12,940
Total imports	29,127	$545,122	29,860	$574,837	22,119	$440,411	25,336	$488,490	26,367	$472,458	22,235	$404,784
Exports	28,103	545,420	57,736	1,076,414	89,221	1,559,761	98,163	1,807,334	37,271	724,679	128,755	2,505,857

MARKETED PRODUCTION OF SULPHUR IN THE UNITED STATES, 1904–1914, IN LONG TONS
(U. S. Geol. Surv.)

Year.	Quantity.	Value.	Year.	Quantity.	Value.
1904	127,292	$2,663,760	1910	255,534	$4,605,112
1905	181,677	3,706,560	1911	265,664	4,787,049
1906	294,153	5,096,678	1912	303,472	5,256,422
1907	293,106	5,142,850	1913	311,590	5,479,849
1908	369,444	6,668,215	1914	327,634	5,954,236
1909	239,312	4,432,066			

Sulphur Mining in the United States

Texas.—The Sugarland Manufacturing Co., which recently constructed a sulphuric acid plant at Sugarland, Texas, at a cost of about $300,000, is now making regular shipments of the refined product. The raw sulphur for the plant at Sugarland comes from the sulphur mines of the Freeport Sulphur Co., near Freeport, Tex., situated about 60 miles south of Sugarland. A direct railroad connection between the two places was recently obtained by the construction of an extension of the Sugarland railroad, which is owned by the same interests that control the sulphuric acid plant and the large sugar refinery at Sugarland.

It is announced that the large sulphur deposits, situated in western Texas, particularly in the vicinity of Orla and Toyah, will be turning out big quantities of sulphuric acid in a very short time. Several companies are now installing equipment for mining the sulphur and manufacturing sulphuric acid in those localities. The Michigan Sulphur Co.

[1] *Min. Jour.*, Nov. 4, 1916.

and the New Orleans Sulphur Co., both of which have large sulphur holdings in that part of the State, have begun preliminary operations. They have already made some shipments of the sulphur and are preparing to greatly broaden the scope of their development work.

The large sulphur deposit situated in the vicinity of Fort Stockton, Tex., is being prospected by the Calumet & Arizona Copper Co. with the view of mining the product and manufacturing sulphuric acid. Large quantities of sulphuric acid are required for leaching copper, and it is for this use that the company is preparing to engage in its manufacture. The demand for the acid for copper leaching purposes is so great that some of the smelters have installed plants for extracting the product from the fumes that come from their plants.

It has long been known that native sulphur existed in enormous quantities in different parts of Texas, but it is only of late years, particularly since the big advance in prices of the refined product and its acid content, that the utilization of this natural resource began to assume big proportions.

The sulphur near Freeport is obtained by the Frasch method of forcing steam into deep wells and converting the product into liquid form and bringing it to the surface by powerful pressure. The underground deposit of sulphur near Freeport is said to be probably the largest yet discovered anywhere in the world. The deposits in western Texas are upon and close to the surface and they cover large areas of the desert region.[1]

Wyoming.—The property of the Midwest Sulphur Co. has an area of approximately 160 acres and is situated in an unorganized mining district 3 miles from Cody, Park County, Wyoming. The sulphur is found in deposits in the silica, lime and sandstone formations and has permeated these formations wherever the ground has been broken, allowing the sulphur gas to come through from the water level below, and depositing the sulphur when coming into contact with the porous rock which is capped with gypsum. The capping of these sulphur deposits is from 1 to 8 ft. thick, and this being removed, development is carried on and the ore taken out by quarry work.

The sulphur at the present workings has been found to extend a distance of 4000 ft. in length, but as to depth and width the extent has not been determined.

Quarry No. 1 has been opened for a width of 300 ft. east and west and has a face of sulphur ore 45 ft. thick with a known width, north and south, of 250 ft. The ore taken from this quarry averages better than 35 per cent. sulphur, and it is of common occurrence to be operating and

[1] *Min. Eng. World*, Nov. 18, 1916.

milling ore that averages 60 per cent. sulphur. The opening into the quarry is about 20 ft. in width and has been driven back 50 ft. and from this work $60,000 worth of refined sulphur has been shipped.

Quarry No. 2 is situated 400 ft. west of No. 1 and has been opened up east and west, for 125 ft., and has a face of sulphur ore 25 ft. thick. The overhead has been stripped for a distance of 25 ft. back from the face and the capping is raising with the slope of the hill and at that distance will give a breast of sulphur ore of 35 ft. This quarry at this time has better ore in the bottom than on top and drill holes in the bottom from 8 to 10 ft. are all in sulphur of good quality. Ore in this pit ran from 35 to 90 per cent. sulphur. The roadway into this pit is to be lowered 8 to 10 ft. and with development work should give a face of 50 ft. There is reason to expect that this body of ore will extend to a depth of 100 ft.

It is the object of the management to make one quarry of No. 1 and No. 2 and when this is done the face will be 900 ft. in length, but this will not be completed before another 12 months have passed. Other development work in the nature of test holes has been done, most of which shows sulphur from 2 to 6 ft. thick.

The mill is equipped with one 80-hp. boiler, two 18-ft. retorts, one 48 in. and the other 54 in. in diameter; a 40-hp. engine, crusher, grinders, water hoist, etc. The Shoshone River flows below the mill and water is pumped with gasoline engine and pump to tank and from there delivered to boilers and other buildings

The usual blacksmith shop, bunk houses, boarding house, office, stables, and other buildings complete its equipment.

The ore coming from the quarries is broken into pieces not larger than 6 in. and loaded in perforated cast-iron cars, holding about 1600 lb. each, three cars being placed in each retort above mentioned. The door of the retort is then closed and sealed and steam turned into retorts and sulphur melted from the ore, the sulphur going to the bottom of retorts where it is drawn off, the gangue rock remaining in the cars. From 3 to 4 hr. are required for each operation. The sulphur is then allowed to cool from 8 to 10 hr. and then carried by hoist to crusher where it is ground and put into 100-lb. sacks ready for shipment.

From the development work now done, and the showing of sulphur ore in the quarries, the management estimates there is at least 7 years' supply of ore in sight, or in round numbers 70,000 tons of sulphur averaging from 35 per cent. to as high as 95 per cent. This is based on a handling of 30 to 35 tons of sulphur ore per day through the mill, and is conservative in its estimate.

The management expects to spend several thousand dollars in development this summer and expressed the belief that by fall at least 100,000 to 150,000 tons of sulphur will be in sight. Allowing for only 100,000 tons and figuring the average content of ore as 30 per cent. sulphur, it will give a gross of 30,000 tons pure sulphur.[1]

The only other sulphur-producing State aside from Louisiana, which produces about 98 per cent. of this country's output, is Nevada, which probably does not produce more than 0.5 per cent. of the total.

Foreign Sulphur Industry

Chile.—The largest producing districts are the Ollague and the Tacora, an account of which may be found in Mineral Industry, **24**, 644.

It is reported that a number of Chilean capitalists have taken steps to exploit the celebrated Tinguirirca sulphur mines, reported to be among the richest in the world, and which contain large quantities of native sulphur.[2]

A concession of mountain land near Antofagasta has been granted to the firm of Errazuriz y Paulsen for the establishment of a sulphur plant. The concession is for 5 years, the Chilean Government reserving the right to terminate it sooner, according to the decree in the Diario Oficial of July 18.[3]

WORLD'S PRODUCTION OF SULPHUR (*a*)
(In metric tons)

Year.	Austria. (*b*) (*e*)	Chile.	France. (*b*)	Germany.	Greece.	Italy. (*b*)	Japan.	Spain.	United States.	Total.
1899......	671	989	11,744	1,663	1,150	563,697	10,241	1,100	1,590	592,290
1900......	985	2,472	11,551	1,445	891	544,119	14,439	750	4,630	581,282
1901......	5,048	2,516	6,836	963	2,336	563,096	16,548	610	6,977	604,930
1902......	3,826	2,636	8,021	487	1,391	510,333	18,287	450	7,565	552,996
1903......	4,610	3,560	7,375	219	1,266	553,751	22,914	1,680	35,660	631,035
1904......	6,431	3,594	5,447	209	1,225	527,563	25,587	605	196,588	767,249
1905......	8,542	3,470	4,637	205	1,126	568,927	24,652	610	218,440	830,609
1906......	15,258	4,598	2,713	178	(*d*)1,000	499,814	27,589	700	298,704	845,956
1907......	24,199	2,905	2,000	176	(*d*)1,000	426,972	33,329	3,612	312,731	801,911
1908......	17,429	2,705	2,189	811	(*d*)1,000	445,312	33,419	13,872	312,700	829,437
1909......	12,856	4,508	2,900	1,185	(*d*)1,000	435,060	36,317	21,750	303,000	817,608
1910......	15,976	3,823	2,641	1,272	....	430,360	43,848	30,113	259,699	787,732
1911......	15,856	4,451	1,200	1,251	174	414,671	52,064	40,662	246,300	776,629
1912......	14,979	4,431	1,000	(*c*)	2,016	357,547	55,005	42,344	308,530	785,852
1913.....	10,561	6,647	659	......	*Nil.*	349,602	59,481	62,653	316,783	806,386
1914......	....	10,008	....	......	*Nil.*	403,558	59,850	(*c*)	333,095	....
1915......	....	(*c*)	....	......	*Nil.*	380,240	61,405	28,937	....	....

(*a*) From the official reports of the respective governments. The sulphur recovered as a by-product by the Chance-Claus process in the United Kingdom, amounting to between 20,000 and 30,000 long tons annually, is not included. (*b*) Crude mineral; limestone impregnated with sulphur. (*c*) Not yet reported. (*d*) Estimated. (*e*) Includes such production from Hungary.

Japan.—The output of sulphur in Japan has recently made a remarkable increase. According to the latest report of the Department of

[1] *Salt. Lake Min. Review*, July 30, 1916.
[2] *Bull. Pan Am. Union*, Jan., 1917.
[3] *Comm. Rept.*, Sept. 1, 1916.

Agriculture and Commerce, the output in April, 1916, reached 2,667,031 kin (3,527,876 lb.), an increase of 50.8 per cent. over the output in the corresponding month of last year. The output for the whole of 1916 was 92,677 metric tons, an increase of 50.9 per cent. over last year. As to the cause of the notable increase, an expert official of that department explains that the biggest markets for Japanese sulphur were, before the war, the United States and Australia. But the exports fell after the outbreak of war, owing to the scarcity of vessels and other causes, and the price showed a remarkable decline, so that the miners were compelled to curtail the production to minimize their economic loss. But this situation has changed since Italy entered the war. The participation of Italy in the war, since Italy is an important sulphur-mining country, must have curtailed its output of sulphur, and this had caused the supply to be short and the demand correspondingly keen in the world's market. Moreover, there has arisen a new demand for Japanese sulphur for war use in Russia, and this has caused the increase in the exports.

The following table shows the exports of sulphur from Japan last year and the year before, classified according to destination:

Countries of Destination.	1914, Pounds.	1915, Pounds.	Countries of Destination.	1914, Pounds.	1915, Pounds.
Australia	52,204,636	63,356,168	Russia	734,815	11,819,997
Canada	3,975,658	11,586,428	United States	41,609,098	60,655,332
India	2,111,053	10,524,868			

Japanese sulphur is produced in the northern districts of the main island of Japan and in Hokkaido. The exports from this consular district, which includes the consular agency at Hakodate, Hokkaido, during 1916, were 21,926 tons, valued at $469,743. The ruling market price at present is $35 per ton f.o.b. Yokohama.[1]

Sicily.—The sulphur situation in Sicily remains strong. Export demand for England, France, Australia, Russia and Sweden has been very active; on the other hand, production has decreased, owing to the fact that the mines are suffering from increased cost of coal, wood, oil and explosives, and to a certain extent from dearth of labor as well, the younger men having been called to arms.

The production as published for the fiscal year of the Consorzio stands as follows: From Aug. 1, 1914, to July 31, 1915, 335,000 tons (of 1000 kg.). During the same period 1915 to 1916, it is estimated that the production will show a decrease of about 10 per cent., say 300,000 tons

[1] *Comm. Rept.*, Feb. 28, 1917.

altogether, and that from Aug. 1, 1916, to July 31, 1917, it will not exceed 275,000 tons. In consequence the prices have advanced considerably, and for a short time the Consorzio offered small parcels only, then withdrew altogether from the selling side. Now they have decided to sell one month about the quantity produced in the preceding month and not to sell for future delivery. They intend also to give the preference to Italian consumers and to those of the allied countries. The Consorzio will expire July 31, 1918, and it is expected that up to that date the stock available will be greatly reduced.[1]

TOTAL EXPORTS OF SULPHUR FROM SICILY
(In metric tons)

Country.	1908.(*d*)	1909.(*d*)	1910.(*d*)	1911.(*d*)	1912.(*d*)	1913.(*d*)	1914.(*d*)	1915.(*d*)	1916.(*f*)
Austria	22,086	26,560	29,601	34,136	38,362	36,335	25,306	70	....
Belgium	8,746	16,377	14,305	11,771	10,723	13,321	5,975	....	....
France	96,448	90,239	93,229	114,868	104,109	21,582	60,773	96,156	107,311
Germany	30,229	28,538	30,225	28,664	32,286	31,042	18,826	391	....
Greece and Turkey	24,838	16,309	21,435	24,933	15,436	20,112	20,746	19,857	15,384
Holland	9,812	8,708	9,731	10,549	14,019	8,976	8,080	1,163	524
Italy	60,134	49,692	61,269	72,959	84,952	85,740	97,170	116,601	76,502
Portugal Spain	17,586	21,036	18,758	25,121	21,314	21,445	17,604	21,004	13,994 8,127
Scandinavia (*c*)	30,366	19,905	20,354	29,741	35,111	28,108	25,294	24,832	26,450
Russia	14,068	18,584	25,866	23,485	25,563	25,891	21,290	2,791	19,947
United Kingdom	20,597	19,860	19,074	19,936	19,830	16,052	12,991	36,156	68,849
United States	9,654	14,706	12,205	8,482	2,856	1,028	1,406	2,054	612
Other countries(*b*)	30,509	33,999	36,935	49,181	42,731	54,185	22,883	38,731	62,440
Totals	375,037	364,513	393,987	453,826	447,292	414,717	338,344	359,806	396,035
Stock in Sicily, Dec. 31	616,419	647,880	640,711	551,442	450,917	376,365	369,001	274,069	155,376

(*a*) Reported by Emil Fog & Sons, Messina. (*b*) Mainly South Africa, Northern Africa, Asia, Australia, and the East Indies. (*c*) Including Norway, Sweden and Denmark. (*d*) Reported by Parsons & Petit, New York. (*e*) Includes Canada. (*f*) Statistics of the International Institute of Agriculture, Rome.

The Thiogen Process for Removing Sulphur Fumes

The Thiogen process for eliminating the deleterious sulphur dioxide from smelter fumes and converting it into free elemental sulphur as a useful product, has been noticed many times in journal notes and articles.

The fundamental chemistry of the proposed process lies in the simple reduction of the sulphur dioxide to sulphur by means of carbonaceous or hydrocarbonaceous materials. In localities where natural petroleum is readily available, it, in some form or other, would be the most desirable material for the purpose. It may be assumed that petroleums are to be used for the purpose, and that their composition is sufficiently closely represented by the formula CH_2. The theoretical equation representing the reduction of sulphur dioxide by such hydrocarbon material is as follows:

$$3SO_2 + 2CH_2 = 3S + 2CO_2 + 2H_2O \qquad (1)$$

[1] *Eng. Min. Jour.*, July 29, 1916.

This equation represents the theoretical maximum chemical efficiency which the process could attain under any condition. It will be seen that, working at this maximum efficiency, 28 tons of hydrocarbon would produce 96 tons of sulphur. This is, of course, taking no account of hydrocarbon used as fuel or for any other purpose.

The patents owned by the Thiogen Co. cover two general methods of carrying out the above-mentioned reduction of sulphur dioxide, one known as the "dry process," and the other as the "wet process." The experimental developments of the two processes have been of wholly different character, and the experiments have been carried out independently.

If one attempts to carry out the reduction of sulphur dioxide by means of hydrocarbon vapors in combustion tubes, very complex and incomplete reactions occur, which result in considerable evil-smelling vapors and much unattacked sulphur dioxide. Even at temperatures too high to be available for practical operations, the reaction is too slow to be of any use. In the investigations leading to the Thiogen patents, a number of satisfactory catalysers were found. These are all compounds of such metallic elements as yield sulphides readily by reduction of sulphates or sulphites, and whose sulphides are infusible and readily converted back to sulphites or sulphates by the action of sulphur dioxide. Such sulphides as those of calcium, barium and magnesium seem to give the best products for this purpose. A little thought will make clear the probable catalytic action of the compounds of these metals.

If we start with say calcium sulphate and treat it at elevated temperatures with hydrocarbon vapors, it becomes reduced to calcium sulphide. If, still at elevated temperature, the sulphide be treated with sulphur dioxide, the following equation represents the reaction which occurs:

$$CaS + 2SO_2 = CaSO_4 + 2S \qquad (2)$$

A few experiments in the laboratory very soon demonstrated the fact that the reduction of calcium or other sulphate to sulphide and its reconversion to sulphate and free sulphur by means of sulphur dioxide could go on readily side by side. That is, if sulphur dioxide mixed with hydrocarbon vapors in the proper proportions is passed through a heated combustion tube containing fragments of calcium sulphate, the reduction of the sulphur dioxide takes place with great ease and rapidity, and the products are mainly sulphur, carbon dioxide, and water vapor. Little or no carbon monoxide is found unless excess of hydrocarbon is used. This is the fundamental principle of the Thiogen "dry process."

The Penn Mining Co., with a smelter located at Camp Seco, Cal., placed at the disposal of the Thiogen Co. ground space, gases, materials, and money for a very considerable series of experiments on a commercial scale. After one or two series of experiments with various forms of apparatus, experience seemed to point to a vertical reaction chamber as best for the purpose. This was constructed of large iron pipe 5 ft. in diameter and 20 ft. high. It was lined with fire-brick, and four stationary hearths were built in. On these hearths was placed the contact material. This was made up of plaster of Paris, which was slopped and allowed to set, after which it was thoroughly dried, and broken into lumps about as large as the hand, so that when installed on the hearths it made loosely porous masses, affording good mixing and contact for the reacting gases. Each hearth was provided with manholes for cleanout and replacement, as well as with tubulations for gas sampling throughout the period of operation. A system of pyrometers was also installed whereby records of temperatures on all the hearths could be obtained.

Below the fourth hearth were the intake for the roaster gases to be treated, and two crude-oil burners. Two burners were used instead of one, to increase the range and accuracy of regulation. The roaster from which the gases were taken was an ordinary McDougal. It was provided with a by-pass system and fan blower, whereby a part of the gases could be continuously returned through the roaster It was thus possible to get gases of fairly constant compositions for sufficient periods of experiment, and under favorable conditions it was possible to maintain a fairly steady flow of gas as high as 11 per cent. sulphur dioxide, for sufficiently long periods to be useful for experiments.

In beginning a run, the procedure was first to start the oil burners, with air draughts, and to keep up the firing until the contact material on all hearths was a good bright red. The air draught was then cut down and the roaster gases admitted. Analyses were continuously taken from all the hearths. These showed at first complete reduction on the first hearth. After a time this hearth began to cool down and reduction was imperfect. The second hearth, however, showed perfect reduction for a time, when this also began to cool off, and so on until the whole apparatus went out of action. This cooling action could be ascribed to two causes: first, absorption of heat by vaporization of the oil; second, the oncoming roaster gases were too cold (they had been cooled to about atmospheric temperature by a scrubber in order to remove dust).

An outside vaporizing chamber for oil was built, and while this assisted somewhat, the same cooling as before occurred. A rather elaborate preheating apparatus for the gases was then designed, but unfortunately at about this time the company encountered difficulties with their mining operations which made it seem doubtful wisdom for them to continue financing the experiments. So the experiments were terminated. In the meantime considerable valuable information had been obtained which is summarized as follows:

1. Under favorable conditions the reaction between sulphur dioxide and hydrocarbon vapors in contact with the calcareous material is extremely rapid. It was never possible to force the apparatus beyond capacity.

2. The process does not offer any hope of working well with gases under 7 per cent. in sulphur dioxide. At lower percentages than this considerable sooting occurs, which puts the contact mass out of commission.

3. In order to operate successfully, the process will demand preheating of the gases. To just what temperature this preheating must go it is impossible to say in absence of experimental evidence. The calculated values do not indicate that it is likely to be an especially difficult matter.

4. The dry process undoubtedly contains the elements of a successful commercial process for producing sulphur, under the condition that the plant producing the gases will operate for high concentration gases. Seven per cent. sulphur dioxide is necessary, and the higher the percentage goes the better, as every drop in sulphur dioxide content means additional oxygen to burn out, and additional oil costs per ton of sulphur.

The Thiogen wet process proposed to accomplish the same end as the dry process, namely the reduction of sulphur dioxide to sulphur by hydrocarbon vapors or carbonaceous material, but it accomplishes this result in a far different way. It was the first of the two processes to be devised. The general procedure in the wet process is as follows:

1. The sulphur dioxide is first absorbed in water in appropriate absorption towers. This operation takes place in accordance with well-known laws and needs no further discussion.

2. This solution of sulphur dioxide in water is mixed and allowed to react with a paste or solution of a suitable sulphide. The most suitable sulphide for this purpose that was found thus far is barium sulphide. When sulphur dioxide reacts with basic sulphides in the wet state, the processes which occur are rather complex. Considerable free sulphur is formed, and in addition, sulphides, thiosulphites and thionates of the metal used. The formation of some complex sulphur salts is a matter of little moment, since in the further operations they break down, and furnish their equivalent of free sulphur.

3. As a result of the treatment described under (2) there is formed a sludge whose solid components are free sulphur and the sulphur salts of the metal used. If the treatment is properly carried out, these solids settle and filter with greatest ease, and the supernatant liquid is prac-

tically pure water, which may again be returned to the absorption towers.

4. The solids of the sludge, after settlement and filtration are dried, and then raised to a temperature of from 450° to 500° C. In this way the complex sulphur salts are broken down and the total sulphur available as free sulphur is distilled off and condensed. The still residue consists of a mixture of sulphite and sulphate together with some sulphide under certain conditions. The sulphide is formed as a result of the well-known breakdown of sulphites into sulphides and sulphates at higher temperatures.

5. The residual sulphites and sulphides are next passed through an appropriate furnace where they are reduced back to sulphide, and are then again ready to be brought into reaction with further quantities of sulphur dioxide solutions. There is thus accomplished a cycle of operations whereby nothing is used up but sulphur dioxide and reducing materials, for which there is produced an output of free marketable sulphur.

The reasons for choosing barium sulphide instead of the cheaper calcium sulphides are chiefly as follows:

1. Barium sulphide is readily and rapidly soluble in water, while calcium sulphide is not. Thus ease of intimate mixing and rapid reaction with the sulphur dioxide liquor is greatly favored by the use of the barium compounds.

2. The sulphite, sulphate and the complete sulphur salts of barium are much more insoluble than the corresponding salts of calcium. This prevents the building up of any disadvantageous concentrations of these salts in the water used in the operation.

3. The barium salts all crystallize anhydrous while the calcium salts all carry water of crystallization in considerable amounts. This means a great saving in the heat demanded in process (4) of the cycle, namely the drying of the filtered sludge. If calcium salts are used, the preparation of the solids for distillation would demand not merely the drying away of adherent water, but also the driving off of large quantities of water of crystallization.

4. The settling and filtering properties of the barium sludges are vastly superior to those of the calcium ones.

As to the relative merits of the two processes, the wet process has the great advantage of operating under present conditions of roaster and blast-furnace operations, namely low concentration of sulphur dioxide. On the other hand, wherever roasting for high concentration could be introduced, the dry process would prove the more economical for the production of sulphur.

Pyrite

The domestic production of pyrite comes principally from the States of Virginia, California and New York, the States being named in the order of their tonnage production. In addition pyrite is mined in the States of Georgia and Missouri and is obtained in the States of Illinois, Indiana and Ohio as a by-product of the coal-mining industry. Some pyrite is also produced in Wisconsin in connection with the zinc-mining industry.

PRODUCTION, IMPORTS AND CONSUMPTION OF PYRITE IN THE UNITED STATES (*a*)
(In tons of 2240 lb.)

Year.	Production.		Imports. (*b*)		Consumption.	
1901	234,825	$1,024,449	403,706	$1,415,149	638,531	$2,439,598
1902	228,198	971,796	440,363	1,650,852	668,561	1,622,648
1903	199,387	787,579	425,989	1,628,600	625,376	2,416,179
1904	173,221	669,124	413,585	1,533,564	586,806	2,202,688
1905	224,980	752,936	515,722	1,780,800	740,702	2,533,736
1906	225,045	767,866	597,347	2,138,746	822,392	2,906,612
1907	261,871	851,346	656,477	2,637,485	918,348	3,488,831
1908	206,471	744,463	668,115	2,624,339	874,586	3,368,802
1909	210,000	756,814	692,385	2,428,638	902,385	3,185,452
1910	223,700	830,150	806,590	2,773,627	1,030,290	3,603,777
1911	299,904	1,150,597	1,001,944	3,788,632	1,301,848	4,939,229
1912	350,928	1,334,259	964,478	3,860,738	1,315,406	5,194,997
1913	341,338	1,286,284	850,592	3,611,136	1,192,930	4,897,421
1914	336,662	1,283,346	1,026,617	4,797,326	1,363,279	6,080,672
1915	394,124	1,674,933	964,634	4,817,977	1,358,758	6,492,910

(*a*) These statistics do not include the auriferous pyrite used for the manufacture of sulphuric acid in Colorado. (*b*) Net imports, less re-exports.
U. S. Geological Survey.

Foreign Pyrite Industry

Pyrite is an extremely precious mineral during the war because it contains three elements of the first order of utility: sulphur, iron and copper. From sulphur is manufactured sulphuric acid, that is to say explosives, and from the iron and copper are manufactured guns and shells. Pyrite may thus be said to be the raw material of all the material of war, or at least contributes to its manufacture in a peculiarly happy manner because of the trinity of its components.

Since the beginning of the war the belligerents have been greatly occupied with the world's pyrite market. But most happily for the Allies, the great producers of pyrite are the neutral countries, first Spain, next Portugal, which has, however, made common cause with the Allies, then Norway. The blockade having interrupted German communications with the Iberian peninsula, the Germans have scarcely been able to supply themselves in the Scandinavian countries whence the Norwegian pyrites have been delivered to them directly or have been transported by way of Sweden and the Baltic. It is not exactly known what Germany has been able to receive from Scandinavia, for the whole production, which is

WORLD'S PRODUCTION OF PYRITE
(In metric tons)

Year	Belgium.	Bosnia.	Canada.	England.	France.	Germany.	Greece.	Hungary.	Italy. (*a*)
1901..	560	4,570	31,982	10,405	307,447	157,433	*Nil.*	93,907	89,376
1902..	710	5,170	32,304	9,315	318,235	165,225	*Nil.*	106,490	93,177
1903..	720	6,589	30,822	9,794	322,118	170,867	*Nil.*	96,619	101,455
1904..	1,075	10,421	29,980	10,452	271,544	174,782	*Nil.*	97,148	112,004
1905..	976	19,045	29,713	12,381	267,114	185,368	*Nil.*	106,848	117,667
1906..	908	13,474	35,927	11,318	265,261	196,971	*Nil.*	112,623	122,364
1907..	397	3,671	35,494	10,357	283,000	196,320	*Nil.*	99,503	126,925
1908..	357	10,403	42,934	9,599	284,717	219,455	6,868	95,824	131,721
1909..	214	7,266	58,645	8,564	273,221	198,688	14,740	98,971	149,084
1910..	213	571	48,871	10,393	250,432	215,708	33,294	92,464	165,688
1911..	122	3,118	74,978	10,276	277,900	217,459	35,960	96,754	165,273
1912..	148	6,216	73,944	10,691	282,202	242,121	29,766	103,809	277,585
1913..	268	3,242	143,882	11,611	311,167	(*g*)228,405	128,880	106,629	317,334
1914..	(*b*)	4,459	204,125	11,848	(*b*)	(*b*)	129,150	102,370	335,531
1915..	(*b*)	(*b*)	259,494	10,711	(*b*)	(*b*)	12,113	(*b*)	369,320

Year.	Japan.	Newfound-land.	Norway. (*c*)	Portugal. (*c*)	Russia.	Spain.	Sweden.	United States.	Total.
1901 ..	17,589	7,532	101,894	443,397	30,732	33,953	*Nil.*	238,582	1,568,999
1902 ..	18,580	26,000	121,247	413,714	26,465	145,173	*Nil.*	231,849	1,713,654
1903 ..	16,149	42,674	129,939	376,177	22,780	155,739	7,793	202,577	1,692,812
1904 ..	24,886	61,166	133,603	383,581	31,667	161,841	15,957	175,992	1,696,099
1905 ..	25,569	51,534	162,012	352,479	30,689	179,079	20,762	228,580	1,789,816
1906 ..	36,038	28,583	197,886	350,746	20,660	189,243	21,827	228,646	1,832,475
1907 ..	56,166	28,000	236,038	241,771	18,316	225,830	27,000	266,061	1,854,849
1908 ..	33,867	(*e*)35,000	269,129	81,417	56,345	263,457	29,569	209,774	1,780,436
1909 ..	27,066	*Nil.*	282,606	284,735	46,078	236,000	16,104	213,371	1,915,353
1910 ..	78,418	*Nil.*	322,000	312,906	55,980	294,184	25,445	227,280	1,860,148
1911 ..	73,879	2,500	(*e*)350,000	282,773	113,054	344,879	30,096	304,974	2,383,995
1912 ..	74,929	*Nil.*	469,326	(*f*)601,443	123,990	421,070	31,835	356,707	3,105,782
1913 ..	114,589	....	441,219	(*f*)391,083	*e*)130,000	926,913	34,319	347,027	3,636,478
1914 ..	115,842	....	414,886	(*a*) 73,404	(*b*)	(*b*)	33,313	342,082	(*e*)3,145,000
1915 ..	67,536	....	(*b*)	(*b*)	(*b*)	730,568	76,324	399,469	....

(*a*) Cupriferous in part. (*b*) Reports not yet available. (*c*) Both iron and copper pyrites. (*e*) Estimated. (*f*) Includes 120,148 tons copper iron pyrite in 1912 and 13,550 tons in 1913. (*g*) Prussia alone.

estimated at 500,000 tons per annum, certainly has not gone in this direction; a part of it has been received in the countries of the Allies, and moreover there is a good consumption on the spot by the country's industries which require sulphurous and sulphuric acids. Finally, it should not be forgotten that the strike of the Norwegian miners which lasted for 4 months in the spring of 1916 sensibly reduced the production for that year.

On the other hand, it was announced on the 5th of September last, that the Norwegian Government had interdicted the exportation of pyrite and cupriferous minerals with a view to the building up of a stock of metal in the country.

This assisted for the moment in the grouping of the Norwegian mines under the shield of a Swedish syndicate which could very well mask the strong German desire for Scandinavian pyrite, which is of the first quality, by grace of its purity and the absence of arsenic. The Austro-Germans are, in fact, poor in pyrite, scarcely 250,000 tons per annum being produced in the deposits in Meggen and Westphalia, while the Austrian pyrite in the deposits in Schwillintz furnishes no more than 100,000 tons. In normal times Germany imports nearly 1,000,000 tons of pyrite, eight or nine-tenths of which it lacks to-day.

France possesses several important deposits of pyrite, and its production which reaches nearly 300,000 tons is superior to that of Germany. From the point of view of sulphuric acid, moreover, France has great latitude for importation. Thus in 1915 France received 257,413 quintals of acid against 110,000 during a normal period like 1913.

But it is the Iberian peninsula which is the great furnisher of pyrite, producing by itself alone two-thirds of the world's production, which is around 6,000,000 tons. In 1915 France received 422,000 tons from the peninsula out of a total importation for that year of 581,000 tons.

The Spanish pyrite market has been strongly influenced by the war. As was the case with all minerals, at the beginning of the war there was an over-production from the fact that hostilities did not permit many contracts to be executed by aliens. Then the sellers who had contracts uncanceled because of the war found themselves in a deplorable situation by reason of the advance in freights. On the other hand, when the sellers themselves were able to place their surplus under long time contracts, which are the rule in this market, ships were lacking. It can, then, be said in a general way that if the price of extracted pyrite f.o.b. Spanish ports has increased 25 per cent. since the war began, this price only applies to a relatively small portion of the exported mineral.

As to the increase in pyrite containing 1 to 2 per cent. of copper, it has benefited by the whole of the advance of this metal since the sulphur and the metal are sold apart, the latter on the base of the best selected.

It is known, in fact, that many buyers of pyrite now consent to allow the sellers a part of the benefit which they obtain by the extraction of the copper after the roasting of the mineral. Under these conditions in lieu of allowing their stocks of mineral to be depleted in copper by lixiviation and cementation in the air for long periods of time, the mines prefer to export their mineral even when it contains more than 1 per cent. of copper.

At Marseilles, on the coast, pyrite is quoted at 65 to 70 centimes per unit and after-the-war engagements are near to 85 centimes.

To sum up, the tendency of the pyrite market, which was already on the advance before the war, will certainly maintain itself along this line once the normal régime has been established, by reason of the great demand which will be maintained for copper and sulphur.

There is also the surplus of the final residue of roasting and of extraction of copper from the pyrite which is known as purple ore and contains around 65 per cent. of iron. This material once briquetted will also bring a good price on account of its high iron content and its low silica, which runs around 4 to 5 per cent.[1]

Canada.—The production of pyrite in 1916 was 309,411 tons, valued at $1,084,019 and included 130,799 tons, valued at $523,196, from Quebec; 177,552 tons, valued at $555,523, from Ontario; and 1060 tons, valued at $5300, from British Columbia. In 1915 the total production was 142,735 tons, valued at $570,940, from Quebec, and 143,303 tons, valued at $414,250, from Ontario.

Exports of pyrite in 1916 were 156,722 tons valued at $557,024, or an average of $3.55 per ton. Exports of sulphuric acid were 3,151,700 lb. valued at $74,527.[2]

The fact that the iron pyrite resources of Ontario are contained within a considerable extent of territory will be shown in the following article; their value is sufficiently indicated by the exports of the last 15 years, totaling 538,755 tons worth $1,438,122. The war has had a stimulating effect on the demand of the United States for Ontario pyrite, and during the coming years this will doubtless result in a steady increase of production.

The majority of the pyrite mines and prospects are concentrated within two main productive areas—the first a narrow belt extending about 8 miles southwest of Brockville, the second a broad area some 20 miles square extending from the town of Sulphide on the east to Madoc on the west.

The earliest mining for pyrite in Ontario was done within this first area on the Billings property, near Brockville, in 1868. Here the main open pit was sunk 250 ft. deep, gouging out the richer ore-shoots and doing no timbering. While operation ceased in 1880, the men who worked in the old pits said they were not completely exhausted.

Steady output of the pyrite mines of the province began in 1898 with the opening of the Bannockburn mine, and mines of Hastings County have been continuous producers ever since. To-day the two main working mines are that of the Canadian Sulphur Ore Co. and the Hungerford of the Nichols Chemical Co.

At the Bannockburn mine, opened as an iron mine in 1898, the pyrite was encountered in two lenses at a depth of 8 to 15 ft. below a gossan of limonite. The south lens was mined for a length of 160 ft. and to a width of from 8 to 15 ft. and to a depth of 275 ft. During 6 years of operation about 580 tons of pyrite per month was shipped to the General Chemical Co. at Buffalo. The quality of ore did not decline with depth,

[1] *L'Echo des Mines et de la Metallurgie.*
[2] *Min. Prod. Can.*, Prel. Rept.

but owing to the hazards of open-pit mining operations were abandoned in 1906.

The Hungerford mine, though opened as a gold mine 40 years ago, was not operated continuously as a pyrite property till August, 1905, when the Nichols Chemical Co. established its title to it. In 1907 this company erected an acid works at Sulphide for the treatment of its own ores and also of other ores bought from the mines of the neighborhood.

The pyrite occurs in three parallel deposits dipping 60° to the south. The north deposit, upon which most of the work has been done, varies in width from 6 to 22 ft. It has been exploited to a length of 620 ft. and to a depth of 575 ft., and the ore still continues. The length as indicated on the surface is about 500 ft. There are now two shafts on the property, and about 3500 ft. of drifting has been done on the ore-bodies on the six levels.

The ore is coarsely granular and makes a large percentage of fines. The main impurity is calcite, although there is also some quartz present. A small quantity of pyrrhotite occasionally occurs, mainly in the north lode next the foot wall. The average percentage of run of mine ore is about 35 per cent., the fines being much higher.

The acid works have been successfully operated since their completion in July, 1907, and machinery has been installed at various times to increase the capacity and to make new acids. At present sulphuric, hydrochloric, nitric and mixed acids are made by the contact process and shipped in the company's tank cars to various parts of Ontario and Quebec. Electric power supplied by the Seymour Power and Electric Co. is used throughout the mine and acid works.

The Canadian Sulphur Ore Co.'s pyrite mine was discovered in 1906 by Stephen Wellington while prospecting for iron. Under the gossan, merchantable iron pyrite was discovered, from which a carload was shipped in 1908. Later the Canadian Pyrites Syndicate bought the property, installed a small plant and shipped a few hundred tons of pyrite. In the spring of 1910 the property was handed over to the present company, which began shipping ore 3 months later and has continued to the present. The mine is equipped to produce 100 tons of iron pyrite per day, yielding 40 per cent. of sulphur. Since Dec. 11, 1912, it has been run by electricity supplied by the Seymour Power Co. A branch line 2½ miles in length from the Bay of Quinte Ry. near Queensboro to the mine was completed in 1913. The ore is shipped to the Nichols Chemical Co.'s acid plant at Sulphide, 11 miles southeast, and to the chemical companies at Hamilton and Detroit.

The pyrite is mined by underground and open-pit methods. The development work consists of three shafts and two open cuts, with some diamond-drill borings. The work in late years has been confined to shaft No. 3 and the two open pits. The vertical shaft No. 3 is 250 ft. deep with about 800 ft. of drifting on the 60-, 120- and 200-ft. levels. The pyrite deposits are marked by gossan outcrops from 2 to 30 ft. in depth. Beneath are the pyrite deposits, which occur as lenses in contact with rusty schist to the south and white quartzite to the north (both Grenville in age) near an irregular post-Hastings intrusion of gray felsite. The strike of the deposits is slightly north of east, while the dip is almost vertical, inclining slightly to the south. Lenses vary in width up to 25 ft., but horses of country rock are frequently inclosed in the pyrites.

The ore is high-grade, requiring very little cobbing if any. Ores have been shipped running 40 to 48 per cent. sulphur. The deposits are free from impurities such as arsenic, zinc, lead, copper and calcium. The pyrite burns satisfactorily and is in good demand by sulphuric-acid makers.

A promising prospect is the Hungerford Western Extension, No. 9 on the map. This was fairly well prospected in 1906 by means of surface trenches at regular intervals along the strike of the fahlband. The western lens had been exploited by surface trenches to a length of 500 ft., exhibiting, near the line between the lots, a width varying from 16 to 18 ft. of ore, which will grade from 42 to 44 per cent. sulphur. The only impurity consists of small included lenses of calcite. The eastern lenses are presumably continuations of the Hungerford mine ore-bodies. A gossan 40 ft. wide occurs on the south end of the property, but not enough work has been done to determine the extent of the deposit.[1]

Spain.—Pyrite exports to the United States from Spanish and Portuguese ports in 1916 as reported by the Spanish agents of the Davis Sulphur Ore Co., amounted to 1,117,968 long tons, from various ports as follows: Huelva, 1,057,326 tons; Seville, 21,100; Pomarao (Portugal) 39,542 tons. Pyrite exports to the United States in 1915 were 874,920 tons and in 1914 were 854,432 tons.

Great Britain.—British imports of pyrite for 1915 were 903,467 tons, of which 751,978 tons were from Spain. It is estimated that the total imports for 1916 will be somewhat over 1,000,000 tons.

Sulphuric Acid

The estimated production of sulphuric acid of strengths of 50°, 60°, and 66° in 1916, expressed in terms of 50° acid, is 4,475,000 tons, an estimated increase over the production in 1915 of 600,000 tons, or more than 15 per cent. The increase was distributed about equally between acids

[1] *Eng Min. Jour.*, Sept. 16, 1916.

of strengths of 50° and 60°, as there was a small decrease in the production of acid of strength of 66°.

The most notable feature in the sulphuric acid industry was the enormous increase in the production of acids of strengths greater than 66°. The estimate shows a production of these stronger acids of over a million tons as against a production of less than 200,000 tons in 1915. It is not feasible to express the amount of these higher acids in terms of 50° acid; therefore the total given for them is in addition to the total given for acids of strengths of 66° or less.

The estimated output of acids of strengths of 60° and 66° includes by-product acid produced at copper and zinc smelters. The output of acid so produced in 1916, expressed as 60° acid, amounted to nearly 950,000 tons, or practically the same as in 1915. However, over 110,000 tons of acid of higher strengths was produced at these smelters, a quantity nearly double that produced in 1915.

The market conditions throughout the country are reported to have been on the whole better than in 1915, and the value of the product will probably be somewhat higher than it was even during that year of high prices.[1]

As the imports of sulphur ore (pyrite) for 1916, were almost a million and a quarter tons, it is quite safe to assume that the production of *pyrite sulphuric acid* was again greater than the high-water mark of the previous year. The domestic and Canadian production of pyrite was also reported to have been larger than for any corresponding period. Brimstone acid has been subject to a heavier demand than ever before for use in explosives, and also in the manufacture of dyes. Early in the year prices ruled at high levels, but as production increased there was a let-up in the keen demand, and slowly but surely the price levels receded. For the last few months, however, there has been increasing call for the acid, and at the present time there is an actual scarcity; many important manufacturers are not taking business for prompt delivery at this time, having well sold up on contract. There has been much complaint regarding the poor quality of the pyrite acid produced in the South. Acid prices have varied considerably, depending largely on location of plant. Northern producers are quoting from $26 to $28 per ton for the 66° brimstone, and from $16 to $18 per ton for the 60° brimstone. Pyrites acid is held at high levels, and Southern manufacturers are asking up to $18 and $20 per ton for the 66° grade, f.o.b. plant. The price for the 60° pyrite ranges from $12 to $15 per ton at works.[2]

[1] U. S. Geol. Surv.
[2] *Met. Chem. Eng.*, Jan. 1, 1917.

PRODUCTION OF SULPHURIC ACID IN THE UNITED STATES IN 1914 AND 1915, BY GRADES IN SHORT TONS

(Figures of the U. S. Gelogical Survey)

Grade.	1914.			1915.		
	Quantity.	Value.	Price per Ton.	Quantity.	Value.	Price per Ton.
50° Baumé..........	1,628,402	$9,712,056	$5.96	(*b*)1,518,271	$10,681,246	$7.04
60° Baumé..........	551,955	3,376,242	6.12	657,076	4,976,453	7.57
66° Baumé..........	916,192	10,509,471	11.47	1,019,024	14,211,381	13.95
Other grades........	65,890	882,158	13.39	(*c*)189,795	2,787,971	14.69
Total...........	3,162,439	$24,479,927	7.74	3,384,166	32,657,051	9.65
Total reduced to 50° Baumé acid.......	(*a*)3,762,417	(*a*)24,163,331	$6.42	3,868,152	29,869,080	7.72

(*a*) Exclusive of 21,993 short tons of fuming acid, valued at $316,596. (*b*) Includes acid reported not only at 50°, but also as 52°, 53°, and 55°. (*c*) Includes stronger acid reported as oleum, etc., carrying varying percentages of free SO_3.

PRODUCTION OF SULPHURIC ACID FROM COPPER AND ZINC SMELTERS, 1912–1915, IN SHORT TONS

(Figures of the U. S. Geological Survey)

Source.	60° Baumé Acid.								
	1912.			1913.			1914.		
	Quantity.	Value.	Price per Ton.	Quantity.	Value.	Price per Ton.	Quantity.	Value.	Price per Ton.
Copper smelters..	(*b*)321,156	*b*) $1,985,704	(*b*)$6.18	336,019	$2,205,627	$6.56	348,727	$2,215,690	$6.35
Zinc smelters....	(*b*)292,917	(*b*) 2,255,237	(*b*) 7.70	296,218	2,140,645	7.23	411,911	2,974,603	7.22
Total.......	(*b*)614,073	*b*) $4,240,941	(*b*)$6.91	632,237	$4,345,272	$6.87	760,638	$5,190,293	$6.82
Total acid reduced to 50° Baumé.	(*c*)764,237	....	....	790,296	....	.....	950,798	....	.....

Source 1915.	Quantity.	Value.	Price per Ton.
Copper smelters, 60°...........................	360,522	$2,749,633	$7.63
Zinc smelters, 60°.............................	484,942	4,292,493	8.85
Other strengths................................	59,189	579,115	9.78
Total..................................	904,653	7,621,241	8.42
60° acid reduced to 50° Baumé.................	1,056,830	....	....

(*a*) The acid reported to the Survey includes that of strength of 50°, 53°, 60°, and 66° Baumé, and a small quantity of electrolyte and oleum. All strengths, with the exception of the electrolyte, have been reduced to both 50° and 60° Baumé, as given in the table.
(*b*) Inclusive of a small quantity of electrolyte.
(*c*) Exclusive of a small quantity of electrolyte.

France.—France has constructed a certain number of factories for its requirements but they are not all in full operation and the French are obliged to import great quantities of sulphuric acid. During the first 8 months of 1916 these importations amounted to 464,131 quintals against 59,000 and 95,000 for the same period in 1914 and 1915.

The United States has greatly developed its exportations of acid, which reached for the year ending June 30, 1916, 371,460 quintals against 211,550 and 54,800 quintals for the 2 years preceding.

South Africa.[1]—The difficulty hitherto experienced by large users of acid in the Union of South Africa, especially by the explosive manufacturers, has been that no local sources of sulphur have been found of sufficient importance to justify the erection of an acid-making plant. It is said that part of such a plant has been erected at Modderfontein for some time past, and the remaining sections would certainly have been completed if sulphur compounds, iron pyrites for example, had been assured in the country itself. For years past enquiries have been made by those interested in the matter, and it may be remembered that the resources of the Witkop zinc mine in this respect were investigated several years ago by the Modderfontein people. Latterly the big occurrences of pyrite at Areachap appear to have met requirements to some extent, and since there is said to be a large reserve of this ore in sight it is likely that the first steps will be taken toward the establishment of a more or less permanent sulphuric acid industry. The existence of a works actually engaged in buying and treating locally produced pyrite will be an encouragement to prospectors and others to find the necessary material. So far, guarantees as to supply have naturally been required by possible purchasers, and it has not been easy to give them. When more exploratory work has been done, as it doubtless will be with the prospect of a regular market, the question of a constant output will probably be a much easier problem than it is to-day.

Russia.—Although pyrite, the raw material for making sulphuric acid, is to be found in large quantities in the vicinity of Ekaterinburg, the largest works in Russia engaged in the manufacture of this acid are situated in the south, and were formerly supplied with material from the pyrites mines of Spain and Portugal. The shortage of tonnage occasioned by the war has caused considerable attention to be turned to the Ural pyrites, and the region now largely supplies the works referred to in South Russia as well as the existing and newly erected works in the Urals. It might be supposed that many new works would spring up in the Urals, but, with the exception of Kyshtim and the Vodarsky works at Polevskoy (Sissert), this is not the case, the reason being that the railway charges on pyrites (the ore) are lower than those on acid, so that it is more advantageous to haul ore from the Urals to the works in the south, where the acid is nearer the market.

The Ural works, with their annual output of sulphuric acid, are as follows: Polevskoy, 600,000 poods (21,668,000 lb.); Roudyanka, 300,000.

[1] *So. Afr. Min. Jour.*, Dec. 9, 1916.

poods (10,834,000 lb.); Kyshtim, 500,000 poods (18,056,000 lb.); and Perm, 300,000 poods (10,834,000 lb.); total, 1,700,000 poods (61,392,000 lb.). The Kyshtim works, which were built in May, 1915, were recently completely burned down. They are being re-built, and it is expected that they will be ready to resume production in April of this year. The total home demand for sulphuric acid is estimated at 20,000,000 poods (722,256,000 lb.) annually, so that the Urals play only a small part in the actual manufacture of the acid, especially when the huge deposits of raw material situated in the Ekaterinburg district alone are taken into consideration.[1]

Sulphuric Acid from Copper Smelting Gases[2]

The last 10 years, and particularly the last 3 years, have witnessed developments in the metallurgy of copper and zinc which involve the use of large quantities of sulphuric acid. These are, of course, leaching and flotation. It is almost always desirable to make the acid at the works using it, because transportation is expensive, and if smeltery gases are available, acid can be made for much less than it can be bought.

There are at least four copper reduction works in this country that have sulphuric acid plants of consequence operating on gases made in the regular course of the reduction of the ores. These are the Mountain Copper Co., whose acid plant at Mococo, Cal., was erected about 12 years ago; the Tennessee Copper Co., whose first unit was built 9 years ago; the Ducktown Sulphur, Copper and Iron Co., whose plant at Isabella, Tenn., was put into operation about 8 years ago; and the plant at the Washoe Reduction Works at Anaconda, which began operating about 18 months ago.

The Mountain Copper Co. plant uses gas from McDougal type roasters, the sulphur-bearing material being fines from the company's heavy sulphide ores. This ore carries 48 to 50 per cent. sulphur. The calcine is treated along with other materials in reverberatories. The acid plant consists of six Meyer tangential chambers with suitable Glover and Gay Lussac towers. The output is about 35 tons of 100 per cent. acid or 45 tons of 60° acid per day.

The Tennessee Copper Co. and the Ducktown Sulphur, Copper, and Iron Co. both use gases from blast furnaces. The Ducktown ores are unusual. They are heavy sulphide ores, the iron mineral being largely pyrrhotite with only a small proportion of pyrite, and the copper mineral being chalcopyrite. The following is an analysis of a typical sample: pyrrhotite, 29.50 per cent.; pyrite, 5.82; chalcopyrite, 7.89; blende, 4.23;

[1] *Comm. Rept.*, Feb. 26, 1917.
[2] *Eng. Min. Jour.*, Dec. 30, 1916.

magnetite, 7.73; quartz, 15.59; silicates, 22.74; calcite, 2.16; and dolomite, 3.56 per cent. The quantitative analysis of this ore is: Cu, 2.74 per cent.; Fe, 30.37; S, 18.87; SiO_2, 26.96; CaO, 66.70; MgO, 2.97; Mn, 0.34; Zn, 2.80; AlO, 2.91.

When these two companies first attempted the manufacture of acid from blast-furnace gases, it was not known just how seriously detrimental to the process the high CO_2 content and the irregular SO_2 was going to be. There were no precedents. It was supposed that the CO_2 would tend to segregate, producing dead corners and perhaps blanketing the bottom acid. It was not a very attractive undertaking, technically. There were two conditions that made it necessary and possible to make acid. The Supreme Court decision in the Georgia case made it imperative to do away with most of the smoke. The fortunate and redeeming feature of the situation was that the plants are situated in the center of the greatest fertilizer-consuming district in this country. A market for the acid was assured.

Tests on the gas delivered by the blast furnaces showed that when they were in good condition, there was an almost complete consumption of the oxygen blown in. By this is meant when no bad crusts or blowholes existed in the charge. This phenomenon was first noted by Robert Sticht in his pyritic work in Tasmania. It was many times confirmed at the Ducktown plant. Some doubt has been expressed at times as to the reliability of these results on account of using metal pipes for drawing the samples in some cases. Numbers of these tests were later made with silica tubes in the gas stream, so that no consumption of the oxygen by the hot metal of a pipe was possible.

The other constituents of the gas were normally about as follows: SO_2, 8 to 9; CO_2, 6 to 7; CO, 0.8 to 1.0; N, about 84 per cent. It was necessary to admit air to this gas in sufficient amount to allow the acid-making reactions to take place and to give some excess-oxygen in the exit gas. Several different methods and proportions were tried. It was a case of being between the devil and the deep sea. If normal oxygen were maintained—that is, 4 to 6 per cent.—in the exit gas, so much air would have to be admitted that the SO_2 tenor of the gas entering would be very low. After trying many different ideas, the Ducktown company decided that the best results were attained by blowing in air at several points in the system. This was done with low-pressure blowers, and the control of the air volume was positive and close. This method is much better than simply allowing flues under suction to draw in air, for drafts always vary from time to time and good control is not certain. The first air was blown in at the flue between the furnace and the Glover tower, and an oxygen content of 3 per cent. was aimed at. Each chamber was fitted with air pipes and valves, and the valves were so manipulated as to maintain from 3 to 4 per cent. oxygen throughout the system at any given point. Below 3 per cent. oxygen, the vigor of the reactions fell off, and the niter recovery in the Gay-Lussacs decreased. This scheme of introducing air at various points as the oxygen is consumed was devised by N. L. Heinz, the company's consulting engineer. While this arrangement was the best one discovered, there was never the same vigorous reaction in the front of the system as that which took place with gas having the usual SO_2 and oxygen percentages.

The effect of the CO_2 was certainly bad, but not in the exact way that had been looked for. Many times for days together the CO_2 percentage equaled or even exceeded that of the SO_2. This occurred when the furnace condition demanded more coke than usual or when the grade of matte became too low; that is, when the sulphur elimination fell off. As to segregation of the CO_2, we were never able to establish any such thing in the chambers. Many tests at different levels and in corners, etc., failed to show CO_2 consistently higher in any parts of the same chamber. The general effect of CO_2 is simply to slow down the reactions and make the process sluggish. It is difficult with high CO_2 to oxidize the last 0.1 or 0.2 per cent. of SO_2, and in order to get a reasonable production, a little SO_2 must be allowed to go to the Gay-Lussacs. This of course makes niter loss abnormal. To compensate to some extent for the deadening effect of the CO_2, a very large niter circulation was maintained, and this also tended to make the Gay-Lussac loss more than normal.

The irregularities of the gas quality and quantity were found to be quite as serious as the CO_2 feature. It is to be expected that blast-furnace gas would be irregular, because of the necessity of frequent opening to charge, to bar down crusts, and to perform many other necessary operations. Changes in the composition of the ore, or irregularities in weighing influence the gas immediately. We were able, by means of the air-blower system previously mentioned, to take care of some of the variations. When, however, the relation of the CO_2 to SO_2 changed considerably, very little could be done except at the furnace. Operating the furnace for gas as well as matte becomes a matter requiring much more skill and attention than when matte alone is the aim.

The problem of exclusion of false air at the furnace top always gave trouble and always will. It is very difficult if not impossible to make tight the top of a copper blast furnace as now constructed.

It soon developed that the acid plants got better gas and could control the process more closely when the flues were so dampered as to create some slight back pressure at the furnace tops. The ideal condition for operating both furnace and acid plant was to have neither pressure nor suction at that point. This was aimed at, but the way it worked out was that the acid plant maintained some back pressure. This made conditions on the charge-floor bad, and the hot gas was very hard on the structure.

The acid systems at the two plants differed greatly. The original Tennessee plant consisted of twelve Falding high chambers, 50 by 50 ft. by 70 ft. high. The idea of this type of chamber was to have each one accomplish the complete process in itself. The gas mixture was admitted at the top, and as the SO_2 gas was oxidized and the vigor of the reaction became less and generated less heat the gas would sink and finally be drawn off at a point near the bottom. The gas movement was originally intended to be accomplished by the pull of the 325-ft. smeltery stack and by steam jets in the connecting flues acting as aspirators. The plant was never very successful while working along these lines, and it was later altered. The chambers were connected in series, fans were added, and the work was much improved.

The results obtained from high chambers are apparently neither better nor worse than those from chambers whose long dimension is horizontal. It certainly saves ground space to have chambers 70 ft. high instead of 30 ft. or less.

The Ducktown company's plant was built more along conventional lines; that is, the chambers were about 24 by 30 ft. by 96 ft. long and were connected eight in a set. Special flue connections between them were designed to mix and cool the gases thoroughly and to prevent segregation of the CO_2. They were quite effective in this, but were rather expensive to build and difficult to repair.

Both plants found it economical to provide unusual Gay-Lussac space on account of the large niter circulation and the sluggish process. Whereas in the usual plant Gay-Lussac volume equal to from 2 to 3 per cent. of the chamber space is sufficient to give 85 to 90 per cent. niter recovery, the Tennessee and Ducktown plants both had near 6 per cent. and had, even then, high losses.

The cost of making acid at these plants was low because there was no charge for sulphur, which ordinarily amounts to about \$3 per ton of 60° acid. Niter cost, as mentioned, was high. Whereas many plants run with from 3 to 4 per cent. niter and some under 3 per cent., these plants on blast-furnace gas used from 6 to 8 per cent. This means, with niter at \$50 a ton, that the ordinary cost per ton of acid for niter is 40 to 50 cts., while the Tennessee plants were doing well under \$1 per ton.

Labor in the South is cheap, so that actual labor cost was low. The number of men required, however, was large owing to the irregularity of the process and to the dirty gas, which made an unusual amount of flue cleaning and tank washing necessary. It should also be said that the irregularities of gas supply, together with frequent complete stops, also the high niter circulation, were very hard on the lead, so that the life of these plants will be shorter than normal, and repair costs high.

The Tennessee Copper Co. operated its acid plant on a mixture of gas from several furnaces. Some doubt was expressed at first as to whether successful operating could be done with only one furnace. The Ducktown company, however, showed that very good work could be done with one furnace alone; in fact, the customary practice there is to run only one.

The acid unit at Anaconda was intended to supply acid for leaching and flotation. The gas is derived from fine jig concentrates from the mill, which carry 35 per cent. S and 7 per cent. Cu. This material is roasted to about 7 per cent. S, which is the grade of calcine desired by the reverberatories. Except for the fact that the ground for a large acid plant was not available within the smeltery site at Anaconda, the plant would have used gas from the regular roasting plant. Because it was necessary to place the acid plant a mile away, separate roasting furnaces were installed for the particular purpose of making acid.

There is nothing unusual about the acid system at Anaconda. It is well constructed, all the buildings being of brick, and is of very pleasing appearance. Exceptionally large chambers are used, 40 ft. wide, 36 ft. high and 96 ft. long. There were originally six of these in series, and later two were added. As this 36 by 40-ft. section gives a low ratio of radiation surface to volume, 29 small circular chambers of 11 ft. diameter by 36 ft. high were introduced among the main chambers to effect cooling and mixing. Two 8-ft. hard-lead fans move the gases.

There is one distinct disadvantage that the Anaconda plant is under. This is the altitude, 5300 ft. above sea-level, with a normal barometer of 622 mm. In the operation of a gas process this matter is of importance. By allowing chamber space in about the ratio of the barometric pressure to sea-level barometric pressure, something over the rated capacity has been produced, with normal niter consumption; that is, about 3.5 per cent. on the sulphur. This has been accomplished without unusual Gay-Lussac space, the ratio being about 3 per cent. of the chamber volume.

One feature of the roasting operation which causes it to lack the simplicity of straight pyrites roasting, is the high copper content—about 7 per cent. This lowers the fusing point of the ore, and on the second and third floors tends to matte and stick to brick and rabbles with the trouble always attendant. This is not serious, but accounts for some daily cutting and renewing of rabbles.

[1] *Eng. Min. Jour.*, Apr. 24, 1915.

At the Garfield plant, near Salt Lake, a chamber-acid unit has been started.

The gases,[1] containing 7 per cent. SO_2, are taken directly from two 20-ft. Herreshoff roasters, with a capacity of 50 tons each per day, passed through approximately 60 ft. of steel flue insulated with fire-brick and silocel, and from thence over the top of a series of 32 lump burners in which are roasted lump pyrite ore. The combined gases then pass to a contact shaft, 15 ft. in diameter and 30 ft. high. This contact shaft is filled with iron oxide and part of the conversion of the SO_2 to SO_3 takes place in this shaft. The gases are then drawn by a fan into the Glover tower, 16 ft. in diameter and 42 ft. high, where they are mixed with the nitric fumes produced in a small nitric acid furnace. From thence the gases pass through a series of six lead chambers, varying in size from 32 by 37 ft. by 54 ft. to 32 by 37 ft. by 93 ft. Between the first and second chamber and the fifth and sixth chambers are intermediate towers 8 by 16 ft. by 37 ft. The gases are sent from the sixth chamber to two Gay-Lussac towers, 20 ft. in diameter and 47 ft. high, and thence discharged into the air practically freed of their SO_2 gas. The acid is returned from the sixth chamber to the first, is then sent by gravity to cast-iron pumping eggs in which it is pumped by air over the Glover tower. This acid is then concentrated in the Glover tower from about 52° or 53° Bé. to 60°, and is sent from the Glover tower to the storage tanks.

The plants described, excepting the Garfield unit, are all straight chamber processes. The Garfield is a combination of contact and chamber, but probably does not rely on the contact for more than 25 per cent. conversion. The fact that all these are chamber plants does not mean that nobody has considered or tried applying the contact processes to metallurgical gases. The contact processes always appear attractive because the plants look small and cheap to build and no high-priced niter is consumed in their operation. But even the owners of the contact processes concede that for making low-strength acid where purity is not essential, the chamber process is considerably cheaper.

Chile.[2]—The plants for this work at Braden are at an elevation of 6800 ft. above sea-level. Wilfley table concentrate from the mill, containing 33 per cent. sulphur and 16 per cent. copper, is fed to a 7-hearth Wedge furnace, having a total roasting-area of 2140 sq. ft. On No. 1 floor the temperature is 380° C.; on No. 7, 630° C. In its passage through the furnace the sulphur is reduced to 3 per cent., while the copper-content is raised to 19.2 per cent.

The sulphur gas is drawn from the furnace by a motor-driven fan of

[1] *Salt Lake Min. Rev.*, Jan. 30, 1917.
[2] *Min. Sci. Press*, June 3, 1916.

hard lead through a brick flue to an octagonal Glover tower of wood and sheet lead, 15 ft. diam. and 43 ft. 2 in. high. The Gay-Lussac tower, 21 ft. 9 in. diam. and 68 ft. high, is of steel, with lead lining and resembles the Glover. Three niter ovens, 3 ft. diam. and 7 ft. 2 in. long, are at the base of the Glover tower. The four lead chambers have a total capacity of 187,000 cu. ft. The wooden frame is covered with ⅛-in. sheet-lead. Water is supplied to the chambers in the form of a spray.

The chambers yield 23 tons of 66° Bé. acid daily, while the Glover tower makes another 5 tons. Chamber acid with a specific gravity of 1.58 is either sent to the mill supply tank for the flotation plant, or to the storage tank at the top of the Glover tower for concentration. The net daily output is from 25 to 28 tons of 66° Bé. acid.

Acid eggs or blow-cases are used for circulating liquors to the towers. Compressed air forces the acids out of them through lead pipes to the desired points. Duriron cocks are used in the pipe lines.

Canada.[1]—The Trail smelter's sulphuric acid plant has been operating steadily since July 1, 1916.

The acid plant itself is a substantial structure, the walls being 180 ft. long, 55 ft. wide and about 40 ft. in height. There are two chambers for holding the acid when made, each of which is 85 ft. in length, 20 ft. wide and 20 ft. high, and has a capacity of 150 tons. The lower 2 ft. contain the condensed or chamber acid, being 65 per cent., which is used in the zinc plant, while the 80 per cent. acid is used in the copper refinery and in the treatment of the slimes, as well as in the manufacture of hydrofluosilicic acid—the latter being produced in an adjoining building.

Sulphur dioxide is brought from the roasters in the electrochemical zinc plant, some pyrites from the Sullivan mine of the company also being used in the manufacture of sulphuric acid.

Originally designed for producing 10 tons of chamber acid per day, the plant is now doing better than that by turning out 30 per cent. more or some 13 tons every 24 hr. When the zinc plant was enlarged and the copper refinery built and then enlarged, the demand for acid was rather heavy—coming almost all at once, as it did, with the desire to fill the huge tanks and vats in the refineries in the shortest possible time, so as to be able to furnish refined metals to fill the insistent calls for the same. Consequently, some acid has been secured from the outside, but in time the local plant is expected to be able to fill all requirements, even though it has to be enlarged, which is not an improbability.

Outside of Trail there are five other sulphuric acid plants in Canada, this being the only one, however, where the acid is produced from the sulphur fumes from roasted zinc ore.

[1] *Min. Amer.*, Mar. 10, 1917.

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TALC AND SOAPSTONE

By Frederick B. Peck

As a result of the demoralized trade relations with other nations, the United States is being forced to rely more and more completely upon its own resources to supply its needs in almost every quarter. During the year 1915–1916 many of the producers of ground talc have been unable to supply the demand for their product and are far behind in filling their orders. This increased demand for talc is in part due to the fact that it is being used in the manufacture of certain kinds of paper as a substitute for English chalk, the price of which has quadrupled, on account of risks in transportation, due to the menace of the German submarines. Again, the increased and steadily increasing demand for talc seems also to be due to the uses made of it in the manufacture of automobile tires and to its further use in the installation of tubes in those tires. The phenomenal increase in transportation and insurance charges on the finer grade of talc imported from France ("French chalk") and Italy, for the manufacture of talcum powder, has had its effect on the relation of supply to demand.

The production of talc and soapstone in the United States for the year 1915 exceeded that of all previous years and more than made good the slight decrease in production of the preceding year, and the indications are that the industry will expand for some time to come. Attention should be directed to the location and development of properties containing the higher grades of talc, such as is used in the manufacture of gas tips, pencil crayons and of talcum powder, for which uses the home supply is far behind the demand. Talc for these purposes must be of the highest grade and therefore brings the highest prices. In 1915 there were but 25 tons of this high-grade talc manufactured in the United States, which sold at the rate of over $300 per ton, while the remainder of the 158,000 tons of ground talc sold at an average price of but $8.42 per ton. Most of the high grades of talc mined in this country come from Georgia and North Carolina. It is to be hoped that the present economic stress, due to abnormal conditions, will stimulate some of the producers in these States to increase their production to the point of supplying home needs.

It seems incredible that the finest grades of talc should not be found in sufficient quantities within our own borders.

PRODUCTION OF TALC AND SOAPSTONE BY STATES

	1912.		1913.		1914.		1915 (*b*).		1916 (*b*).	
	Tons.	Value.	Tons.	Value.	Tons.	Value.	Tons.	Value.	Tons.	Value.
New York	66,867	$656,270	81,705	$788,500	86,075	$821,286	88,214	$864,843	93,236	$961,510
Vermont..	42,413	275,679	45,547	327,375	50,698	363,465	61,997	406,652	73,215	501,175
Virginia...	25,313	576,473	26,487	615,558	21,687	527,938	3,036	18,579	8,798	73,622
N. J. and Pa.	10,400	50,519	11,308	80,780	7,732	54,549	7,989	56,466	8,222	59,331
North Carolina	3,542	63,304	4,676	48,817	1,198	28,413	1,454	21,501	1,787	41,824
California	1,169	15,653	952	6,000	547	8,786	712	7,185	1,130	13,694
Georgia	....	....	....	....	....	....	498	12,050	6,921	111,686
Other States	9,566	69,065	5,158	41,067	4,359	60,650	2,786	15,143	(*a*)	(*a*)
Total...	159,270	$1,706,963	175,833	$1,908,097	172,296	$1,865,087	166,636	$1,401,197	193,309	$1,762,842

(*a*) Massachusetts included with Georgia, Maryland with California. (*b*) Talc only.

Talc only.................................. Georgia, California and New York.
Talc and soapstone........................ North Carolina, Vermont, and Virginia.
Talc and serpentine........................ New Jersey and Pennsylvania.
Soapstone only............................ Rhode Island.
Pyrophyllite................................ North Carolina.

The table above shows the production of talc and soapstone by States for the years 1912 to 1916 inclusive. The total production of talc and soapstone in the United States for the year 1915, was 186,891 short tons, having a value of $1,891,582, which was an increase of 14,595 tons and $26,495 in value over the production of 1914. The production of soapstone alone in 1916 was 19,652 short tons, almost entirely from Virginia, with a small amount from California.

Of the mine-producing States, New York continues to hold first place, with a production of over 50 per cent. of the total output of the country and a gain of 2139 tons (2 per cent.) over her production for 1914. Vermont holds second place with a production of 37 per cent. of the total output and a gain of 11,799 tons (37 per cent.) over the amount produced in 1914.

The United States produces more talc and soapstone than all the other nations combined, as will be seen on consulting the table below. France is the second largest producer with less than half the production of the United States. The Canadian output has increased steadily in the last 10 years. It reached its highest point in 1914, with a production of 12,250 tons. In 1915 it was 11,885 tons, valued at $40,554; nearly one-half of which (4797 tons) was shipped to the United States.

Reports for 1916 give 11,810 tons. All of the talc mined in Canada comes from the vicinity of Madoc, Ontario.

Talc is quite a common mineral in Rhodesia, South Africa, where it occurs in large bodies in a more or less pure form. During the past 2 years it has been possible to maintain an export trade to Europe, especially to England, because of the curtailed supply of "French chalk" (talc). The prices range from $40 to $200 per ton according to the quality. This talc is largely consumed in the manufacture of paint, paper and cotton fabrics, and it is being substituted for "French chalk" in the manufacture of rubber tires for motor cars.

PRODUCTION OF TALC AND SOAPSTONE BY COUNTRIES
(In tons of 2000 lb.)

	U. S. (*a*)	France (*b*)	Italy (*c*)	Canada. (*c*)	Spain. (*d*)	Austria. (*c*)	Ger. Empire, Bavaria. (*d*)
1907	139,810	38,262	13,574	1,534	....	15,294	2,203
1908	117,354	37,053	12,048	1,016	5,214	....	2,424
1909	130,338	38,433	13,228	4,350	6,154	....	2,537
1910	150,716	42,316	13,727	7,112	5,143	....	3,308
1911	143,551	44,092	15,600	7,300	6,226	15,212	3,728
1912	159,270	60,629	15,800	8,270	(*e*)	(*e*)	3,551
1913	175,833	(*e*)	23,530	12,250	(*e*)	(*e*)	(*e*)
1914	172,296	(*e*)	24,271	10,808	(*e*)	(*e*)	(*e*)
1915	186,891	(*e*)	(*e*)	11,885	(*e*)	(*e*)	(*e*)
1916	(*c*)193,309	....	....	11,810	....	....	....

(*a*) Talc and soapstone. (*b*) Talc, soapstone and asbestos. (*c*) Talc. (*d*) Soapstone. (*e*) Statistics not available.

Talc is reported from various localities within the ancient crystalline rocks of Brazil. Those deposits more favorably located with reference to transportation and markets are now being worked. Of these localities, the following may be mentioned: Rezenda, State of Rio de Janeiro, where a very pure white talc is produced, suitable for the manufacture of talcum powder; Lorena and Santo Amaro, both in the State of Sao Paulo.

Massive talc, or steatite, occurs in different parts of the country, as near Itaberaba, municipo de Ouro Preto, Varzea near Dores de Boa Esperanca, and near Jacuhy in the western part of Minas Geraes. At these places its principal use is in the manufacture of cooking utensils, which are turned out on the lathe from solid blocks of soapstone. Pans and pots of this material are specially prized in Brazil for cooking rice. It also occurs in Ceara and Goyaz.

TIN

By Baliol Scott

Viewed in retrospect, 1916 is one of the most interesting years that has ever been experienced in the tin industry. The expectation of important intervention by United States interests in controlling the production of some portion of their requirements of the white metal; which seemed indicated by the events of 1915, has now taken shape and as a result we face a position analogous to that which is to be observed in other branches of the metal industry, namely the creation of fresh reduction plant which appears to be much in excess of the production capacity of the world. The situation has a certain parallelism with that of spelter, though the factor of limitation is not, as there, consumption, but the world's capacity to produce the ore. An important result of this condition is that, whereas the end of 1915 saw the world with an accumulation of ore supplies due to the closing of the German market, the outlook now is for a shortage of ore, so much so that some of the smelters at any rate contemplate turning their attention to the treatment of their slags, which have naturally been permitted to accumulate as long as the supplies of ore were in excess. This question will be considered more in detail in a later part of this article. What tends to accentuate the prospect of a shortage is the decline which is apparent in the production of tin ores and the difficulty which the writer at any rate experiences in foreseeing sources of supply from which the decline among older producers can be made good. At the time of writing—early in May—it is difficult to judge how the situation may look at the considerably later period when publication of this article takes place and an opinion certainly exists in many quarters that a marked advance may be seen on the current price of about £233 per ton, and this may bring an increased production in many quarters. At the same time the writer fails to see much prospect of the diminishing tendency being checked so far as the aggregate production of 1917 is concerned. In a sense the foregoing considerations may be said to belong to 1917 rather than to the past year, but the causes which have produced them are to be found in the history of 1916, and even earlier, and to that extent, therefore, some reference to them is necessary in a review of last year's features.

The Tin Market

The marked feature of the year was, of course, the continued development of the tin consumption of the United States in relation to that of the rest of the world. The consumption of metals in the United States was on an unprecedented scale, and with an article like tin, which is a diminishing rather than an expanding quantity, the effect was unusually pronounced. In addition to the ordinary channels of shipment to the Atlantic ports, the United States Steel Corporation, which now figures as a regular buyer in the Straits, imported a very large amount of metal by direct shipment to the Pacific Coast. The deliveries as given by the New York Metal Exchange were 43,350 tons at Atlantic ports and 12,866 tons at Pacific ports, making a total of 56,216 tons for the year as compared with 50,387 tons in 1915. In addition to this metal a considerable quantity of concentrates was shipped into the United States from Bolivia amounting, according to advices from Pacific ports, to 8124 metric tons. How much of this was actually converted into metal and delivered to consumers it is not easy to determine, but the calculation of the New York Metal Exchange report is that 3800 tons of metal from these sources was disposed of. This total added to the metal actually imported gives a grand total of 60,016 tons of tin delivered to consumers in the United States during 1916. If we take the figures of arrivals in the States we get a still higher figure, as the total landings of metal are given as 58,356 tons, giving with the production of the American Smelting and Refining Co. a grand total of 62,156 tons of metal. Figured in pounds the import figures for the past 12 years read as follows:

IMPORTS OF TIN INTO THE UNITED STATES

Year.	Pounds.	Value.	Year.	Pounds.	Value.	Year.	Pounds.	Value.
1905..	89,227,698	$26,316,023	1909.	95,350,020	$27,559,937	1913.	104,282,230	$46,900,314
1906..	101,027,188	37,446,508	1910.	105,137,740	33,921,449	1914.	95,049,612	32,861,188
1907..	82,548,838	32,075,091	1911.	106,936,872	43,390,639	1915.	115,636,332	38,736,909
1908..	82,503,190	23,932,560	1912.	116,003,385	50,371,102	1916.	138,073,293	51,803,384

The increase in supply was in Dutch and English tin which aggregated 13,309 tons compared with 6683 tons in 1915. The tendency toward higher prices in New York as compared with London parity showed a tendency to increase during the year. The average monthly prices of tin, according to the figures of the *Engineering and Mining Journal*, were as follows:

MONTHLY AVERAGE PRICES OF TIN IN 1914, 1915, AND 1916

Month.	New York.			London.		
	1914.	1915.	1916.	1914.	1915.	1916.
January	37.779	34.260	41.825	171.905	156.550	175.548
February	39.830	37.415	42.717	181.556	176.925	181.107
March	38.038	48.426	50.741	173.619	180.141	193.609
April	36.154	47.884	51.230	163.963	166.225	199.736
May	33.360	38.790	49.125	150.702	162.675	196.511
June	30.577	40.288	42.231	138.321	167.636	179.466
July	31.707	37.423	38.510	142.517	167.080	168.357
August	*	34.389	38.565	*	151.440	169.870
September	32.675	33.125	38.830	*	152.625	171.345
October	30.284	33.080	41.241	*	151.554	179.307
November	33.304	39.224	44.109	139.931	167.670	186.932
December	33.601	38.779	42.635	147.102	167.000	183.368
Av. year	....	38.590	43.480	....	163.960	182.096

New York in cents per pound; London in pounds sterling per long ton. *No quotations.

In the current year this disparity has been accentuated so far as spot metal is concerned, but the writer is not in a position to judge how far it affects the bulk of the supplies. It is generally recognized that the advance in price last year barely corresponded to the increased costs of production, transport and smelting, in fact in many cases it is clear that mines were working at a loss.

World's Production and Consumption

The world's statistics of tin are this year later than ever, and it is possible to present official statistics only in one or two cases; in the others estimates or shipments to consuming countries alone are possible. With these reservations the following figures are presented in the belief that they will not require much modification:

	1916, Tons.	1915, Tons.	1914, Tons.
Malaya	43,870	46,766	49,042
Bolivia	21,145(*b*)	21,794	22,356
Banka	14,548	13,773	13,973
Siam	7,800	7,800(*a*)	6,800
Cornwall	4,500	4,968	5,056
Billiton	5,000(*a*)	5,750	4,000(*a*)
Nigeria	5,075	4,555	4,517
China	3,800(*a*)	3,012(*b*)	1,824(*b*)
Australia	5,000(*a*)	2,312(*b*)	1,544(*b*)
South Africa	2,003	2,089	2,094
Total	112,741	112,819	111,206

(*a*) Estimated. (*b*) Shipments to Europe and United States.

The writer can not attempt to present with any confidence figures of consumption under the present conditions when official statistics are so largely withdrawn. As noticed above American deliveries are estimated at 60,016 tons. The net imports into the United Kingdom were 18,474 tons, to which must be added 4500 tons from Cornwall, making a total available for consumption in the United Kingdom of 22,974 tons, as compared with 32,762 tons in the previous year. The visible supply of concentrates in the United Kingdom, which at one time reached the total of 12,900 tons, steadily declined during the latter part of 1916 and stood at about 6000 tons at the end of the year. Since then these stocks have been further depleted, but to what extent is not known. The British tinplate production was less than three-fifths of a normal year and that of Germany and Russia probably ceased entirely so far as the tin considered in these statistics is concerned. The United States production totalled about 295,000 tons above that of 1915, so that for rough purposes it may be said to have offset the diminished United Kingdom consumption. What the consumption was in tin for alloys for bearing metal and other purposes can not be gaged; it can only be said that it would be proportional to the aggregate world's production. It may be hazarded that the consumption on the whole showed an increase, owing to the abnormal requirements of the United States. The very high prices which have been ruling of late in France and Italy for tin suggest that war uses to some extent have developed in tin as in practically all other metals. The French were reported at one time to be lining shells with a film of tin as a protection against corrosion by acid.

Tin in the United States

There has been further prospecting activity in the United States in the hope of revealing native deposits. Occurrences have been noted in the Northern part of Lander County, Nevada, 20 miles North of Battle Mountain on the Southern Pacific Railroad. The occurrences have been reported on by Adolf Knopf,[1] of the U. S. Geological Survey. The discovery in Nevada may or may not be of economic importance, but it calls attention to a novel and remarkable type of deposit and, still more important, it opens up possibilities of prospecting in the enormous areas of rhyolite flows in the Great Basin and elsewhere in the West. Very similar deposits have been known for some time in several States in Mexico, particularly Durango and Guanajuato. The ore is a kidney-shaped or mammillary cassiterite, which is associated with hematite, chalcedony, opal, tridymite and quartz, a most peculiar combination from a mineralogical standpoint. It is believed that the veins result from the action of hot waters, which near the surface have extracted emanations from the rhyolite very soon after its solidification. The

[1] Contributions to Economic Geology, U. S. Geol. Surv., 1916.

uncommercial character of the tin deposits of similar character in Mexico prevents us, however, from being very sanguine respecting the similar deposits in Nevada.[1]

Alaska remained as heretofore the only commercial producer. The output was 232 tons of alluvial tin as compared with about 200 tons in the previous year. Of this about 162 tons came from the York district, where two tin dredges were operated and a third was working on placer ground carrying both tin and gold. Developments were also continued on the Lost River lode-tin mine. The rest of the concentrates were recovered incidentally to placer-gold mining in the Hot Springs district of the lower Tanana basin.[2]

Tin in Foreign Countries

Malaya.—One of the features of the year was the continued decline in the output from the Federated Malay States, which amounted to 3196 tons—an even larger decline than in 1915, when the falling off was 2433 tons. At the present time, owing to the interruption in mail communication and the postponement of the Annual Government Report, full details of the year's working are unavailable. The output for recent years is as follows:

FEDERATED MALAY STATES' TIN OUTPUT

	1911. Pikuls. (*b*)	1912. Pikuls. (*b*)	1913. Pikuls. (*b*)	1914. Pikuls. (*b*)	1915. Pikuls. (*a*)	1916. Pikuls. (*a*)
January	64,333	67,566	69,232	83,711	73,834	72,506
February	53,147	72,545	64,219	59,725	63,495	56,659
March	50,132	53,698	59,842	64,508	61,374	62,094
April	54,568	67,270	68,305	68,655	60,806	53,368
May	62,868	71,849	72,563	69,471	64,225	62,651
June	64,202	59,465	67,078	72,275	68,003	57,508
July	63,799	71,175	71,318	76,985	59,540	59,080
August	68,592	74,831	77,613	60,330	67,971	62,690
September	62,862	69,133	73,574	60,869	66,051	61,082
October	68,764	65,605	74,080	65,656	63,785	61,846
November	66,334	69,087	66,790	(*d*)63,639	66,739	61,055
December	62,091	71,248	77,522	(*d*)63,206	67,220	66,277
Totals	(*c*)741,698	(*c*)813,472	(*c*)842,136	809,630	783,043	737,016

(*a*) From *The Mining Journal.* These figures show the monthly exports of tin and tin ore (the latter being stated at its assumed metal content) upon which duty is paid to the F. M. S. Government. (*b*) 1 ton (2240 lb.) = 16.8 pikuls. (*c*) Finally revised figures. (*d*) Exclusive of Pahang, etc.

There can be no doubt that the main reason for this decline, which as will be seen amounted in 2 years to 5629 tons of metal, was the great decrease in the number of coolies employed. The mining labor force in the F. M. S. at the end of 1916, exclusive of holders of dulang passes, was 139,143 as against 164,457 in 1915, 171,689 in 1914 and 225,405 in 1913.

[1] *Eng. Min. Jour.*, Jan. 20, 1917.
[2] U. S. Geol. Surv.

The labor force, including holders of dulang passes, was in 1916, 153,150 and in 1915, 180,316, distributed as below:

State.	1915.		
	Labor Force.	Dulang Passes.	Total.
Perak	94,865	9,667	104,532
Selangor	52,050	4,946	56,996
Negri Sembilan	6,901	429	7,330
Pahang	10,641	817	11,458
Total	164,457	15,859	180,316

State.	1916.		
	Labor Force.	Dulang Passes.	Total.
Perak	82,534	8,488	91,022
Selangor	43,389	4,195	47,584
Negri Sembilan	4,399	473	4,872
Pahang	8,821	851	9,672
Total	139,143	14,007	153,150

There was, therefore, a decrease in mining coolies, exclusive of holders of dulang passes, of 25,314 between 1915 and 1916, and 86,262 between 1913 and 1916. The principal reason for the decrease in the mining labor force last year was that a number of coolies were attracted to rubber estates, where they can earn from 60 cts. to $1 for a short and not very arduous day's work. The wages of male Chinese labor were $11.50 per month, the Towkay providing food, or $18 per month without food. Female Chinese labor earned $16 per month. The contract price per chiang, *i.e.*, 30 by 30 ft. by 1½ ft., for lifting overburden ranged on the average $24 for deep land, $19 for medium depth and $15 for shallow mines.

While the decline in the labor force is in one sense the primary cause of the decline in output, it is from a still wider viewpoint a symptom of the economic position. The Chinaman is naturally a miner and if a considerable quantity have by preference turned their attention to planting it is because the price of tin, though high, was not particularly lucrative. The shortage of tonnage was felt and the high freights have presented an ever-increasing charge upon the industry. The price of coal rose considerably, while the price of rice and opium were substantially above the 1915 figures; the cost of mining and smelting materials advanced considerably and it was at times impossible to procure machinery or spares from England, and all timber, whether for fuel or structural purposes, was dearer and scarcer. As will be seen, the export was practically the same as in 1910. The decline was quite general. The State of Pahang, which for many years showed a growing output, recorded a decline of between 20 and 25 per cent. The following table gives the production by States in recent years:

PRODUCTION OF TIN BY STATES (*a*)
(In pikuls of 133⅓ lb.)

	1907.	1908.	1909.	1910.	1911.	1912.	1913.	1914.	1915.	1916.
Perak........	431,386	467,784	461,665	421,335	437,339	477,240	493,753	479,621	466,634	457,660
Selangor.....	273,900	282,540	266,007	240,192	231,175	255,382	252,765	244,665	234,155	205,650
Negri Sembilan	75,155	64,221	48,072	34,697	29,230	29,071	36,821	35,900	20,900	15,240
Pahang.......	33,195	39,520	43,144	40,674	43,954	51,779	58,791	63,723	63,980	54,464
Total.......	813,636	854,065	818,888	736,898	741,698	813,472	842,130	823,909	785,670	737,014

(*a*) Exports of tin ore, the latter being calculated to its assumed metal contents, upon which duty is paid to the F. M. S. government.

The shrinkage of production was marked in the State of Selangor, being for 1916, 28,505 pikuls (1697 tons), or 12.17 per cent. The State of Negri Sembilan showed a decrease of 5660 pikuls (337 tons), or 27.08 per cent. Pahang also showed a decrease of 5516 pikuls (328 tons), or 8.62 per cent. Perak continued to be the largest exporter, producing more than half the total exports of the F. M. S., and the output remains fairly steady. In that State a large number of mines are worked with European capital and by up-to-date methods and labor-saving machinery. The dredges are a big feature in Batu Gajah, Ipoh and Taiping. The hydraulic mines at Gopeng and Tekka continued to work successfully, and maintained large outputs. There are no mines in Selangor worked by the dredge system, all being open-cast and mostly in the hands of the Chinese. Selangor is becoming more interested in agriculture than formerly, and the output of tin ore is likely to decrease steadily. This is even more noticeable in the State of Negri Sembilan. Pahang has had sudden bursts of mining energy, but these are never maintained for very long. The State requires developing before an increase in output can be expected. An Australian company is at present erecting a large dredge in Bentong to work the late Mr. Loke Yew's lands, and work is expected to commence shortly.

This decrease has become more accentuated in the current year. The output for the first quarter, despite the fact that the estimated content of the tin ore has been raised from 70 to 72 per cent., was 1785 tons lower than in the corresponding quarter of 1916. If this rate of decrease be maintained, the falling off will be much more serious than in either of the 2 preceding years.

The year 1916 opened with conditions in Europe daily becoming more serious. The industries of most European countries, beyond the manufacture of guns, munitions and weapons of warfare generally, were at a standstill. The position, however, as regards America, the largest consumer of tin, was abnormal; Japan also became a large dealer in the metal. The price of tin has been well above normal during the year; the market opening the year at £175 17s. 4½d. for 3 months, the local price on same day being $85.34, and closing at £177 15s. 0d. for 3 months, local price on the same day being $82.40. The average price for the year was $87.61 as compared with $78.23 in 1915. The highest price reached was $97.50 on May 4 and the lowest $77.25 on July 20. For the first time the declining output in the Federated Malay States was reflected in the shipments of metal from the Straits. Despite the fact that the Federated Malay States' export has shown as follows in tons: 1913, 50,127; 1914, 49,042; 1915, 46,766, Straits shipments in the same years showed successive increases. This was attributable to the fact that the Straits Trading Co. has obtained all the South African production and an increasing amount from Australia, and that there has been a growing output from Siam. The smelting works also has been added to, as pointed out in last year's MINERAL INDUSTRY. In 1916, however, a marked change set in and the shipments were reduced to 63,372 tons, a decline as compared with 1915 of 4707 tons. Details are given in the accompanying table:

STRAITS SHIPMENTS OF TIN

	1912, Tons.	1913, Tons.	1914, Tons.	1915, Tons.	1916, Tons.
January	3,997	5,949	5,327	5,100	6,120
February	5,256	4,666	6,527	5,555	6,200
March	5,142	4,814	4,118	5,037	5,183
April	4,235	4,301	4,914	4,357	4,645
May	5,753	6,176	6,899	6,550	3,890
June	4,302	4,824	5,877	6,800	6,230
July	4,381	4,793	5,100	5,620	5,410
August	5,366	6,011	3,840	4,797	4,425
September	5,475	5,152	5,100	5,244	3,345
October	4,422	5,015	3,785	4,426	5,875
November	5,642	5,662	5,709	6,723	5,591
December	4,996	5,105	6,404	5,370	4,661
*Sundries	2,790	2,140	2,000	2,500	1,797
Totals	51,757	64,608	65,240	68,079	63,372

* To India and China.

Belgian Congo.—No figures are available of production from this source, but small parcels of ore reach British smelters at irregular intervals. Owing to the disorganization caused by the occupation of Belgium by the enemy and the fighting which has taken place on the borders of the Congo territory, it is quite impossible to obtain any official figures. The Congo remains simply a potential producer at a future date.

Portugal.—Some supplies have been received in the United Kingdom during the war, but as interest is predominantly in tungsten, the writer has not been able to obtain actual figures. The output is not likely to exceed some 200 or 300 tons at most.

Siam.—Here unfortunately no representative figures are available. The Siamese output in recent years has been a steadily expanding one—one of the few countries in fact to show an increase. It is *primafacie* improbable that the output exceeded that of 1915. Most of the increase in the last 2 or 3 years has been due to the dredging industry and it was impossible in any way to add to the plants last year, and the absence of spares and the difficulty of carrying out ordinary repairs are adverse factors for the dredges actually operating. The output of the Siamese Tin Dredging Syndicate was 903 tons as compared with 901 tons in 1915. The dredges working the Tongkah harbor for the 12 months ending Sept. 30 last are reported to have obtained 1077 tons.

Dutch East Indies.—The official returns of the output from the Banka mines for the working year 1916–1917 give a production of 239,613 piculs (14,548 tons), a decrease of 127 tons from the preceding year. The total for 10 months was 159,358 piculs (9485 tons) against 145,249 piculs (8646 tons), an increase of 839 tons, but the great bulk of the output is obtained from these mines toward the end of the working year. According to Messrs. G. A. Witt's figures, published at the beginning of the year, the production amounted to 14,097 tons, but this period of course does not coincide with the official year, which is the Chinese. The large accumulation of tin which had collected in Banka in the earlier months of the war was very largely liquidated. The total shipments during 1916 are estimated at 19,847 tons. Since the beginning of the year the balance of the surplus of the metal is understood to have been disposed of. The output of Billiton for the 12 months ending May, 1916, was 94,858 piculs (5759 tons). The imports into the United States in 1916 of Banka and Billiton amounted to no less than 7575 tons as compared with 590 tons in 1913.

No information is available to the writer as to details of working either at Banka or Billiton.

At the end of the year the Netherlands Trading Co.'s stock was 1136 tons. The Banka tin imported by the Netherlands Trading Co. during the year was sold for home consumption only, and the Dutch tin market was closed throughout the year.

Great Britain.—The better price for tin did not offset the shortage of labor and the increased cost of working generally. The writer estimates the output as nearly as possible at 4500 tons, compared with 4968 tons for 1915. The great difficulty in Cornwall, as indeed in lode tin mines everywhere, is the absence of developed reserves, and when the mines find their complement reduced by over 40 per cent., which is the experience of the chief mine, Dolcoath, the difficulty of maintaining their position becomes very serious. In some directions, too, the Excess Profits Tax has undoubtedly operated to restrict activity, but this is a result which should be more felt in the future than in the past year. Early this year it was announced that at any rate during the war, the Government had taken control of the coal mines of the country, and later on it was reported in the House of Commons that this measure had been extended to the metal mines. A committee of the Munitions Department has recently been appointed to consider the development of the mineral resources of the United Kingdom for the purposes of the war. Exactly what is being done it is difficult to ascertain, but the exact position of the lessees and Lords in Cornwall at the present time in relation to the State action is certainly obscure. State assistance has been given in the case of some of the wolfram properties and, of course, it might be extended to other minerals. So far as development in the mines is concerned, very important discoveries have been made at East Pool; but Dolcoath had not at the time of the last meeting in February last been able to make any discoveries in the limited amount of prospecting that was possible with the shortage of labor.

It is doubtful if any of the purely tin producing mines made any profit last year. East Pool, South Crofty and Clitters produce wolfram which is highly profitable, and the price of arsenic has been at an exceptionally high level. The high prices which have developed in tin since the beginning of the year are, however, unfortunately of little permanent use to the Cornish mines, as they have not got the labor to profit by them.

Nigeria.—The output from Nigeria last year showed an improvement, the exports amounting to 7250 tons of concentrates, or 5075 tons of metal, against 6507 tons for the previous year, equal to 4556 tons of metal, an increase of 520 tons. No general report is yet available of the working last year. Nothing has transpired to modify the impression conveyed in last year's MINERAL INDUSTRY as regards prospects of permanence of these fields and of an increasing output. In 1915 prospecting showed a definite decrease and the area held under exclusive license was lower than in any year since 1910. The number of stream mining licenses was lower, while that of mining leases was somewhat larger. Details of the chief producers during 1915 were as follows:

	Black Tin, Tons.	+ or − on 1914.	Colored Labor.
Rayfield	665	+ 54	953
Naraguta	599	−118	1,067
N. N. (Bauchi) Tin	456	+ 50	764
Mongu	402	+274	836
Ex Lands Nigeria	397	+170	381
Ropp	396	+ 59	405
Jos	366	− 42	314
Niger Co.	316	+205	897
Bisichi	314	+ 59	391
Forum River	309	− 52	640
Naraguta Extended	274	+123	469
Anglo-Continental	258	− 14	661
Kaduna	239	− 13	402
Jantar (Nigeria)	193	+ 24	380
Nigerian Tin Corp.	170	+ 56	667
Lower Bisichi	129	....	263
Tinfields of N. N.	120	....	229
West African Mines	115	− 9	262
Tin Areas of Nigeria	115	....	301
Benue	108	....	329

South Africa.—The export from South Africa last year showed some decline and amounted to 2003 tons of metal, compared with 2089 tons in the previous year. The deposits in the Bushveldt country are erratic and the fortunes of the individual companies always fluctuating. The chief companies operating last year were the Rooiberg Minerals, Leuwpoort Tin and the Zaaiplaats Tin. The output of the Zaaiplaats for the year ending July 31, 1916, was 531 tons of concentrate, as against 699 tons in the previous year. Additional ground was subsequently taken in and some improvement was manifested in the returns. The Rooiberg Minerals at the end of March, 1917, announced that owing to the failure to locate fresh ore-bodies the output would probably be reduced. The output from the Cape only amounted to 27 tons. What is being done in the territory which was formerly German Southwest Africa, it is not possible to learn, as no statistics are published. In Rhodesia the tin deposits have remained dormant.

China.—No direct information is available as yet as to working conditions in Yunnan during last year. A United States Consular Report gives the exports as follows in slabs of 112 lb.:

Exported to.	1913, Slabs.	1914, Slabs.	1915, Slabs.	1916, Slabs.
Great Britain	8,047	20,892	27,492	22,373
Continent of Europe	32,575	5,644	17,843	4,800
United States and Canada	36,790	24,699	47,617	48,864
Total	77,412	51,235	92,952	76,031

The decline in export is attributed to the appreciation in the value of the silver dollar, which greatly diminished the profit on exports in the latter part of the year. In the same report it is stated that there was a stock accumulated of some 3600 tons in warehouse at the end of the year. If so, with present prices (May, 1917) it has probably been since liquidated. Such an amount is somewhat surprising, as when added to the exports it practically equals the Yunnan output, and this implies that there was no export at all into China. According to a report in the *Mining and Scientific Press,* the Wah Chang Mining & Smelting Co. proposes erecting a tin smelting plant in Hunan. The output, however, from this source has not been large enough in the past to suggest anything of importance. The exports of 3800 tons mentioned in the Consular Report above are much in excess of those credited in the London tin trade. Messrs. A. Strauss & Co. give the imports of Chinese tin into the United Kingdom and United States as 1305 tons. It is, of course, possible that the Japanese took a considerable supply, though this is not indicated in the Consular Report.

Australia.—Complete figures are not yet available. It would appear, however, as if the output would not vary very much from the figures of the preceding year. 3212 tons of concentrates was smelted at Mount Bischoff for a return of 2219 tons of metal. The dredges in New South Wales produced 1372 tons of concentrates, an increase of 108 tons on the year. In Queensland the output was 1707 tons of concentrates, showing a decline of 418 tons. This gives a total of 6291 tons of concentrates, without allowing for the production from lode mines in New South Wales and for any Tasmanian ores exported. The equivalent in metal would probably be about 4090 tons. Shipments from Australia to the United Kingdom are given as 2482 tons. The improved yield was mainly due to the wet season. Large producers like Mt. Bischoff in Tasmania and the Vulcan in Queensland showed considerably reduced outputs. The production of the Ardlethan field in New South Wales was about 350 tons of concentrates. Including the production from Western Australia, the total Australian output last year should be about 5000 tons.

Bolivia.—Bolivia has perhaps been the most interesting of the world's centers of tin production during 1916. This is due to the fact that it is the only direction in which American capital has been free to act, so far as securing supplies of ore on a large scale is concerned. The Bolivian tin industry has been in a transition period owing to the cutting off of one of its chief selling markets, Germany. In 1913 Germany imported 15,831 tons of concentrates out of a production of 44,594 tons. This ore had to find fresh markets and this circumstance has given American interests their opportunity. Important smelters were established in 1915 by the American Smelting & Refining Co. and it is reported that these will be enlarged to a capacity of some 12,000 tons of metal. In addition the National Lead Co. has in prospect the creation of smelting capacity up to 20,000 tons. The Andes Exploration & Smelting Co. has started a small electric smelter near La Paz and the Compañia Chilena de Fundicion de Estaño is being established at Arica in Chile. If published plans mature these American plants will dispose of an aggregate capacity of some 35,000 tons of metal, whereas the output of Bolivia last year the writer estimates at 21,145 tons. This is a reduction from recent years as the accompanying table shows.

EXPORTATION OF TIN ORE FROM BOLIVIA
(In metric tons)

Year.	*Barrilla.* Tons.	Tin Contents. (*a*)	Year.	*Barrilla.* Tons.	Tin Contents. (*a*)	Year.	*Barrilla.* Tons.	Tin Contents. (*a*)
1901..	21,573	12,943	1907.	27,678	16,607	1913...	44,594	26,756
1902..	17,340	10,404	1908.	29,938	17,963	1914...	37,259	22,355
1903..	21,785	13,071	1909.	35,566	21,340	1915...	36,324	21,794
1904..	20,369	12,221	1910.	38,548	23,129	1916...	35,097	21,145
1905..	27,690	16,614	1911.	37,073	22,434	....	....	....
1906..	29,370	17,624	1912.	38,378	23,027	....	....	....

(*a*) Tin content of the barrilla (black tin concentrate), computing the latter at 60 per cent. metallic tin.

It is therefore obvious that there will be keen competition for ores. This process is illustrated already in the case of the Llallagua mine. It was understood that the American Smelting & Refining Co. had secured the output from this property, but in a recent United States Consular Report it is stated that the erection of the Chilean Tin Smelting Co. mentioned above is being done for the owners of the Llallagua Tin Co. The capital is stated to be Chilean and the mines at Llallagua. The report proceeds as follows: Durward Copeland, one of the engineers, is an American, professor of metallurgy at the Missouri School of Mines, and has traveled in Cornwall, China, Straits Settlements, and Bolivia, gathering data. He will import the necessary skilled labor, and is now at Arica, Chile. It is thought the smelter will have about 7000 tons of 60 per cent. (or over) tin barilla from the Llallagua mines, and should easily find 3000 to 5000 tons more from other producers. Construction work has been started, the Chilean Government assisting the smelter company with grants of land and water rights.

United States engineers last year examined a good many properties, and it seems reasonable to expect that if the smelting plants mentioned materialize to the extent foreshadowed, American capital will have to buy mines and develop them on a very considerable scale. This raises many important questions. A Bolivian does not sell mines on the basis of the amount of ore developed. When Messrs. Jackling and Hayden toured Bolivia last year they inspected various tin properties, but so far as is known were unwilling to pay the prices asked. How far the ad-

POTOSI

	Metric Tons.	Bs.
Uncia	8,416	10,351,550
Llallagua	5,812	7,148,691
Velarde	3,376	2,922,681
Ore buyers	2,760	3,381,647
Oploca	1,966	2,417,887
Cerro-Rico	1,078	1,325,700
Chocaya	726	892,430
Chorolque	605	744,381
Sala Sala	484	595,673
Molino	484	595,539
San Joaquin	243	299,141
Colquechaca	243	298,827
Cotani	167	205,419
Ocurí	132	163,447
Agua de Castilla	92	113,084
Sagrario	88	107,950
Andacava	55	67,855
Guari-Guari	51	62,590
Tazna	32	48,117
Hagao	22	27,423
Carguaycollo	22	27,010
Concordia	21	26,260
Choraya	20	24,782
Buen Retiro	20	24,658
San Vicente	20	24,131
San Antonio	19	23,093
Pulacayo	10	12,015
Consolidada	9	11,341
Maragua	9	10,566
Candelaria	6	7,933
Alianza	5	6,573
Esmoraca	1	2,044

ORURO

	Tons.	Bs.
Huanini	1,697	2,086,891
Morococala	1,440	1,770,918
Ore buyers	1,138	1,402,632
Socavón	728	895,022
Avivaya	602	762,620
Totoral	513	631,548
Oruro	429	527,275
San José	342	420,434
Pazña	289	355,137
Negro Pabellón	174	213,501
Itos	122	150,331
Antequera	85	104,004
Challapata	32	38,840
Challa-apacheta	29	35,933
Vinto	24	32,117
Sepulturas	17	20,337
San Cristo	8	9,385
Eucaliptus	4	5,486
Japo	3	3,751

LA PAZ

	Tons.	Bs.
Viloca	622	765,408
Araca	529	650,209
Milluni	317	390,355
Quimsa Cruz	293	359,868
Berenguela	243	299,248
Chocñacota	224	275,219
Concordia	114	140,616
Solano	98	120,237
Quime	58	71,871
Colcha	57	70,640
Colquiri	52	64,068
Tuesuhuma	45	55,589
Bajaderia	39	47,938
Andes Tin Company	29	36,066
Santiago	21	25,356
Yaco	19	23,133
Kami	14	17,049
Ocavi	11	13,111
Jatuncaka	9	11,316
Villaque	5	6,296
Ore buyers	3	3,755
Achachicala	2	2,502
	36,492	44,885,450

vance in tin prices and the evidence of greater competition may have modified the decision then arrived at, only the future can show.

Among those who have mined in Bolivia in past years, the impression has taken root that the output can not be seriously increased without the labor question being tackled in a radical manner and the trouble is that, climatically, imported labor is of very doubtful efficacy owing to the elevation at which most of the mines stand.

The great bulk of the Bolivian concentrates are at present treated in England and the English smelters would not be disposed to forego their supplies without a struggle. Sr. Patino, the largest producer, is understood to have contracted his output to Williams, Harvey & Co., though for what period is not known. This supply will under the merger recently arranged between the National Lead and Williams, Harvey & Co., Limited, be available for smelting either at Liverpool or in the United States, as may be found most convenient. Moreover, when the war is over German smelters will naturally try and recover some of their lost trade, for like the United States they have practically no other field from which to draw ore if the present regulations of the British Government preventing the export of ores to foreign countries should be continued. It will be seen, therefore, that the position of Bolivian mine owners is one with great possibilities.

Thus far the Customs output for last year is not available. Reports of shipments from Pacific ports aggregate 21,145 tons. This is considerably below the pre-war figure.

Particulars of the geology and ore treatment at a number of important Bolivian producers were published in the *Engineering and Mining Journal* in the course of last year.

It may perhaps be of interest to give particulars of the Bolivian producers in 1915, which were reported as shown on page 711, grouped under the shipping centers.[1]

Tin Smelting

As indicated in the opening of this article, the most striking feature of 1916 was the increase, actual and prospective, in the tin-smelting capacity of the world. This is the more interesting when the declining tendency of the tin output is taken into consideration. Since the outbreak of war the Straits Trading Co., the Eastern Smelting Co. and Williams, Harvey & Co. among British firms have added considerably to their capacity. At the end of 1915 the American Smelting & Refining Co. started up a plant in New Jersey with a reported capacity of 5000 tons of tin per annum. The actual production last year has been reported

[1] *Min. Jour.*, Aug. 26, 1916.

at 3800 tons and it has been frequently stated in the United States press that the capacity is to be doubled. More important still are the projects of the National Smelting Co., operating through their subsidiary, the Williams, Harvey Corporation. A plant is being constructed, which it is officially stated by the company is to have an eventual capacity of 20,000 tons of metal. At Arica in Chile the Llallagua Tin Co. are reported to be building a smelter with a 5000-ton capacity. There is also an electric smelter reported to have made a trial run at La Paz, the capacity of which is not given. If all these projects are carried through it will be seen that interests in which American capital is interested project an increase in the smelting capacity of the world of roughly 40,000 tons per annum, and there are the additions made in the Straits by the two big smelting companies to add to this. In estimating the smelting capacity now existing or projected it will, of course, be realized that an exact figure is somewhat difficult to arrive at. The writer has made inquiries from leading firms, who in some cases are willing to furnish statistics and in others not. The figures must not be pressed too closely as in some cases current production was given and in others obviously the capacity only can be indicated. Where the figures are official they are indicated with an asterisk; in other cases they are the best figures that could be arrived at from inquiries in the trade:

	Tons.	
Great Britain.		
* Williams, Harvey & Co.	17,000	
* Penpoll	5,500	
Cornish Tin Smelting Co.	4,200	
Capper, Pass	2,500	
Redruth Tin Smelting Co.	1,500	
London Tin Smelting Co.	400	
		31,100
United States.		
* Williams Harvey Corporation	20,000	
* American Smelting & Refining Co.	10,000	
		30,000
South America.		
Chile Tin Smelting Co.	5,000	
Andes Exploration & Smelting Co.	?	
		5,000
Australia.		
* Mt. Bischoff (1916 not pub.)	3,212	
Woolwich Tin Smelting Co.	1,000	
Irvinebank	?	
		4,212
China.		
Kochiu Smelters, about	7,000	
		7,000
Straits Settlements.		
Straits Trading Co.	36,000	
* Eastern Smelting Co.	17,000	
Chinese (1916)	5,000	
		58,000
Dutch Indies.		
Banka and Billiton	16,000	
		16,000
Grand total		151,312

It is, of course, obvious that no exact computation can be given of the amount of tin produced in the primitive Chinese furnaces, which like any other native furnace is quite elastic and is constructed or dismantled as occasion requires. The production from these furnaces in the F. M. S. last year amounted to just under 5000 tons, and a considerable amount of the output from Yunnan is similarly produced, as well probably as a certain amount from Siam. Not many years ago the bulk of the Straits output was produced in the primitive Chinese furnace and refined either in Penang or the Straits Settlements and even at present the Yunnan tin finds its way to Hong Kong for refining. More and more the industry tends to be concentrated in the hands of the big companies, who offer sellers better terms than the native ore buyers, and in an estimation of actual capacity the Chinese smelter has little more than a local significance. It is probable that with the Butterworth Extensions the Straits Trading Co.'s output is now beyond the figure given. The shipments from the Straits were 64,000 tons last year, while the capacity shown is 6000 tons lower. Part of this may be Chinese smelters outside the F. M. S. and the rest is probably The Straits Trading Co. The Banka companies probably smelted from 1500 to 2000 tons last year.

At the present time tin reduction shows signs of being concentrated in three parts of the world, the Straits, Great Britain and the neighborhood of New York. In the East the Straits Trading Co., at present much the largest producers, have shown great energy in the past. The evidence given before the Australian Tariff Commission in 1914 and 1915 showed that the local smelting companies had great difficulty in holding their own. The Straits Trading Co. had its buyers throughout Australia, and the evidence of the tin miners was unanimous that they could get better terms than from the local companies, while the Mt. Bischoff Co. and the Sydney Tin Smelting Co. said that they must have protection to continue. So far as the writer is able to ascertain the whole of the South African output is also taken by the same concern. The English smelters obtain the whole of the Nigerian output and since the war the great bulk of the Bolivian. How far this will remain in their hands will depend upon the amount of capital which American firms propose to devote to endeavoring to capture this trade. In view of the big undertakings now on foot it is quite evident that competition will be keen. The general outlook in view of the great disproportion between production and capacity certainly leads to the impression that the smaller producers will tend to disappear unless they are artificially protected.

Metallurgy

There is nothing to report as regards progress in tin dressing, as will readily be understood when the conditions affecting research in the Allied countries is considered. In connection with the British Government's grant for the study of the question in the United Kingdom, some inquiry appears to be on foot; but for the present, so far at least as the writer has heard, it appears to be mainly in the way of suggestion to the tin industry to try what has at one period or another been turned down as impracticable, and it is improbable that the matter will receive any consideration from those practically acquainted with the industry during the war. Speaking generally, innovations in regard to the tin industry are not successful. Chief interest, of course, attaches to the new smelting works and to recent extensions in older ones which are in hand, but if any new features are introduced they are not published. It is reported that the electrolytic refining plant installed at the American Smelting and Refining Co.'s Perth Amboy works has been given up, and certainly smelting opinion in Great Britain does not believe in the method. No doubt with the much higher prices now ruling for tin and the competition which will result for the available ores, more attention will be paid to as high a recovery as possible. In the past 2 years with the accumulation of ores in Great Britain the consideration of treating the largest possible amount of tonnage has taken precedence of extraction, and no doubt most of the English smelters have considerable residues for further treatment.

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TITANIUM

By L. E. Barton

Considering the comparative abundance of titaniferous ores and the many suggested applications of titanium compounds, it appears that the development of the titanium industry has been comparatively slow. The reason for this condition probably lies in the fact that most of the suggested applications require the use of very pure titanium compounds, and such have not been available at reasonable prices. Recognizing this condition extensive investigations have been conducted during the past few years both in this country and in Europe, directed to the production of pure titanic oxide and other compounds which would be available as intermediates for application in the arts and for the preparation of special titanium products. Notable in this regard is the development of a process for making a particularly pure titanic oxide. The process is described in U. S. Patent No. 1,189,229, July 4, 1916, granted to L. E. Barton, assignor to the Titanium Alloy Manufacturing Co.

Titanium is largely used in the form of its ferro-, copper and other alloys as a deoxidizer and cleanser for molten metals such as steel and titanium-aluminium bronze. Some of the salts of titanium find considerable application in the textile and leather industries for dyeing, mordanting, and bleaching. Titanium is also used in limited quantity in the ceramic, dental, metal-enameling and arc-lighting industries.

Application of titanium compounds for abrasives, paint, tanning of leather, manufacture of ammonia, etc., has been suggested.

Concentrating and Smelting of Titaniferous Ores.—The large deposits of titaniferous iron ore continue to receive the attention of investigators who realize that the ore from some of the deposits can be magnetically concentrated, yielding an iron concentrate low in phosphorus and sulphur and comparatively low in titanium, suitable in admixture with other ores for the blast furnace. The tailings from such concentration are suitable for making ferrotitanium, either used directly or after concentration of the ilmenite, by tables of the Wilfley type or by other means.

An investigation on the smelting of titaniferous iron ores has recently been conducted by Stansfield and Wissler.[1] Their experiments, which

[1] The Smelting of Titaniferous Ores of Iron, by Alfred Stansfield, F.R.S.C., and W. A. Wissler, *Trans of the Royal Society of Canada*, Series III, Vol. 10.

were conducted in a small electric furnace, confirm the results of some older investigations, indicating that titaniferous ores can be smelted without special difficulty provided that silica as well as limestone is used as a flux.

An important feature of their work is the investigation of fusibility of titaniferous slags, the results of which are shown graphically by means of a chart. The chart shows a large area of fusible slags in the middle of the diagram, containing about equal proportions of lime, silica and titanium.

The authors conclude that conditions are not favorable to large-scale competition with the richer imported hematite ores; but since the ores are frequently low in the phosphorus and sulphur they would find a field as an addition to an ordinary blast-furnace charge, or for the whole charge for a charcoal blast furnace or an electric furnace, for the production of special qualities of charcoal iron commanding a high price.

Ferrotitanium.—With a better understanding of the nature and methods of using ferrotitanium, resulting from extensive investigations for a number of years, both by the manufacturers and users, the industry reached an unprecedented development during the year 1916.

The rail tonnage treated with titanium shows little change from the previous year, figures for the past 8 years being as follows:

	Tons.		Tons.
1909	35,945	1913	47,655
1910	256,759	1914	23,321
1911	152,990	1915	21,191
1912	141,773	1916	26,493

The increase in titanium-treated steel has been due to general application to all grades of steel where specifications as to quality have been exacting, such as axles, tires and other forgings, galvanized sheets, tin plate and castings.

While exact figures are not available, a conservative estimate based upon sales of the alloy and recommendations for use in various grades of steel, indicates a total of about 2,000,000 tons of titanium-treated steel during the year 1916, or an increase of 100 per cent. over corresponding estimate for the previous year.

Textile and Leather Industries.—The shortage of dyes, mordant and other chemicals resulting from European war conditions has had the effect of attracting the attention of textile and leather manufacturers to already known applications and stimulated the development of new applications of titanium compounds to these industries.

The chlorides, sulphates and oxalates of titanium are used, but of these the last-named in the form of titanium potassium oxalate is most in demand. This salt has recently been quoted at 53 cts. per lb. as against 25 to 30 cts. prior to the war.

The application of titanium compounds for dyeing and mordanting of both wool and cotton fabrics is described by Mr. Joseph Barnes[1], as follows:

"The most striking feature of titanium from a tinctorial point of view is the formation of the brownish-orange compound when its salts are mixed with tannic acid. This compound, when deposited on the fiber of textiles, varies from a light yellow to a deep yellowish-orange, and is very resistant to light and to washing. As a means for fixing tannic acid on the fiber, titanium is quite as efficient as antimony, and for certain shades the yellow color of the titanium tannate is an advantage when the yarn or cloth is subsequently dyed with a basic dye. The method of applying a solution of tannate of titanium to oxalic acid (tanno-oxalate) is so simple, quick, and effectual that it is surprising it has attracted so little attention. The shades of yellow and gold are pleasing, and in the case of mercerized cotton are especially so, seeing that the luster of the material is not impaired by the process. During the shortage of dyes titanium has undoubtedly a distinct use in enabling one to produce certain shades of green, red, and brown from basic dyes which are still procurable.

"The titanium tannate color may be modified by mixing certain alizarin or allied colors with the tannin 'prepare,' passing through a titanium bath—either the oxalate or the sodium-titanium sulphate—and developing the shade by boiling in water or steaming, part of the titanic oxide in this case acting as a mordant for the alizarin.

"Cotton already colored with tannin-titanium may be dyed up with alizarin orange, alizarin brown, alizarin, etc., and if the dyeing is carried on for a sufficient length of time practically the whole of the tannic acid becomes replaced by the alizarin dye. An addition of acetate of lime to the dye bath may in some cases be advisable. It is thus an easy matter to obtain a great variety of fast art shades by this process, which may be summarized as follows: Pass through a bath of tanno-oxalate of titanium, wring up or squeeze, pass through a hot bath of common salt, wash and dye up with the alizarin.

"It would seem that the tannate of titanium might serve as a ground for khaki shades on cotton as well as upon wool. Attention may be drawn to the fact that quite a good scarlet may be produced on wool mordanted with titanic oxide by dyeing with alizarin orange. Certain precautions have to be taken in order to get a bright shade. The materials must be as free as possible from iron, and care must be taken to avoid the change of the titanic oxide into the meta condition. A sufficiency of oxalic or tartaric acid must be used in the mordanting bath, and prolonged boiling must be avoided. Tartaric acid seems to have a better effect in preventing the change to the meta state than oxalic."

The application of titanium salts to the dyeing and mordanting of leather is discussed by Ashworth.[2] Titanium salts in conjunction with tanning materials form a yellowish-brown lake which is fast to light and to the action of alkali salts. The potassium titanium oxalate is used in the dyeing of both chrome and vegetable tanned leathers.

Directions are given for the use of the salt and for the production of

[1] *Jour. Soc. Dyers and Colourists*, May, 1916.

[2] Potassium Titanium Oxalate as a Dye, Stainer and Mordant. *Leather World*, **8**, No. 2, 15–6 (1916); *Shoe and Leather Reporter*, **121**, No. 9, 77–7 (1916).

a large variety of colors by its use in conjunction with dyewood extracts.

Lighting.—Both rutile and ilmenite are used for making arc lamp electrodes.

Patents for arc lamp electrodes containing titaniferous materials have recently been granted to I. Ladolf, Cleveland, Ohio, Assignor to W. D. Edmonds, Boonville, N. Y., U. S. Patent No. 1,164,728, Dec. 21, 1915; and to C. R. Krueger, Schenectady, N. Y., Assignor to General Electric Co., U. S. Patent, No. 1,173,005, Feb. 22, 1916.

Enamels.—A limited but steady demand continues for specially prepared "Titanellow" in Potters' ceramic and dental grades at the antebellum figures of 40 cts. to $2 per lb.[1]

It has been proposed to use titanium compounds, particularly the oxide, in place of tin oxide for the opaqueing of white enamels, and several patents have been taken out during the past few years purporting to have solved this problem. Notwithstanding these efforts, no progress seems to have been made in the industrial application of titanium compounds for this purpose, probably on account of the slightly yellowish tone accompanying their use. The solution of this problem probably depends largely upon the production at a reasonable price of a sufficiently pure titanic oxide.

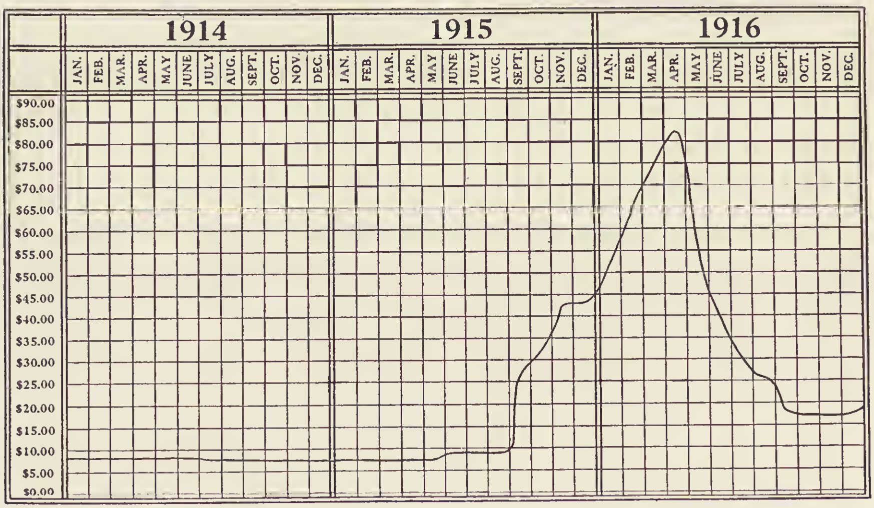
New Uses of Titanium Compounds.—The use of titanium compounds as white pigments for paint and other purposes is the subject matter of U. S. Patent No. 1,205,144, Nov. 21, 1916, granted to L. E. Barton of Niagara Falls, N. Y., assignor to the Titanium Alloy Manufacturing Co. It is expected that this new field for titanium will require large quantities of rutile, ilmenite, and other titaniferous materials.

[1] *Eng. Min. Jour.*, Jan. 6, 1917.

TUNGSTEN

By Colin G. Fink, Ph. D.

The year 1916 has been another record year in the tungsten industry. The "boom," which had started in the fall of 1915 and which had been brought about by the large war orders for high-speed steels, continued through the greater part of 1916, reaching a climax in April when the unit of 20 lb. of tungstic acid sold at $82.50 compared to $7.75, the average price in 1914.[1] The burning down of the important Atolia mill contributed to the heavy fluctuations. During the last 4 months of 1916 the



THE TUNGSTEN PEAK OF NINETEEN FIFTEEN-SIXTEEN

Fig. 1.

unit was quoted at $17 and $18 and the production in the chief tungsten centers continued strong to the close of the year.

In plotting the above curve,[2] published quotations in the Eastern mining journals are used from June, 1915, to December, 1916. However, from January, 1914, to May, 1915, only Western published quotations

[1] For ore price schedule see *Eng. Min. Jour.*, July 22, 1916; also *Met. Chem. Eng.*, April 15, 1917.

[2] Curve taken from *Mineral Foote-Notes*. The Foote Mineral Co. published no tungsten prices prior to July, 1916. Thereafter they published to consumers as follows. (Approximate average on different ores); July, Aug., $26.00; Sept., $21.00; Oct. $18.00; Nov., $16.00; Dec., $17.00.

The decline was probably even sharper than indicated by the curve.

appeared. The Western are here advanced about 10 per cent. to approximately include transportation to the East. Prices are understood to be for ore or concentrates guaranteed to contain 60 per cent. or more tungsten trioxide (WO_3), and are per unit (1 per cent., or 20 lb.) of WO_3 per net ton.

The total output of concentrates in the United States in 1916 was almost 7500 tons, or three times that of 1915, and equal to about one-third of the world's output. The United States outstripped Burma and regained its position of first tungsten producer of the world. There is more ferberite and scheelite mined here than in any other country and as to quality of concentrates, the American product has no rival. Much of the foreign product is contaminated with tin.

In the table below the weights are given in short tons of concentrates of 60 per cent. WO_3, which is the commercial basis in this country.[1]

PRODUCTION OF TUNGSTEN CONCENTRATE IN THE UNITED STATES
(In tons of 2000 lb., 60 per cent. WO_3)[2]

Year.	Production.	Value.	Average per Ton.	Year.	Production.	Value.	Average per Ton.
1907	1,640	$890,048	543	1912	1,330	$502,158	$377
1908	671	229,955	343	1913	1,537	672,118	438
1909	1,619	614,370	379	1914	990	435,000	439
1910	1,821	832,992	457	1915	2,332	4,100,000	1,760
1911	1,139	407,985	358	1916	7,469	31,500,000	4,200

Stimulated by high prices, methods of milling and concentrating were improved in all of the important centers and recoveries here averaged 90 and 91 per cent. as compared to 75 and 80 per cent. in 1914.

Among the foreign producers, Japan, Portugal, Argentina and Bolivia showed remarkable gains over 1915. Russia entered the field as a tungsten producer; Mexico continued her tungsten developments in spite of difficulties; and Canada again became a producer. The base price in the British Empire was fixed by the government at 55s. per long ton unit of 65 per cent. concentrates.

The price of tungsten in the United States as metal or as ferro-tungsten fluctuated a good deal during the course of the year. In January it was $6.00 to $6.50 per lb. of metal content, in May it was $8.50 to $9.50 and closed in December at $2.40. The price before the war was 67 cts. per lb.

The imports of tungsten ore, according to the Bureau of Foreign and Domestic Commerce, were 3635 tons valued at $7,353,691 as compared with 1595 tons valued at $1,044,536 in 1915. The imports of tungsten metal and ferro-tungsten in 1916 amounted to 38 tons valued at $157,711

[1] In the British Empire and most other countries the basis is 65 per cent.
[2] Statistics reported by F. L. Hess, U. S. Geol. Surv. Figures for 1916 preliminary.

as compared with 7 tons valued at $9588 in 1915. There was considerable agitation among the mining centers of the West over protective tariff legislation for tungsten ore and tungsten products; it is hoped that a bill will be put into effect in the new year.[1]

The exports of tungsten in 1916 amounted to 574,321 lb. valued at $1,352,631. Before the war very little was exported, so little that the Government published no separate records.

United States

Alaska.—Though scheelite has long been known to occur in some of the Alaska placers, up to the last 2 years the demand for it has not been sufficient to encourage its recovery. The high price of tungsten induced Alaska miners to turn their attention to scheelite deposits. In the fall of 1915 a scheelite-bearing vein was discovered in the Fairbanks district. Later two others were found. Crude scheelite ore was shipped during the summer of 1916. Considerable scheelite was also recovered from some of the gold placers at Nome. About 50 tons of scheelite concentrates were produced in Alaska during 1916 for which the producers received over $50,000.[2]

Arizona.—During the first 6 months of 1916, 175 tons of concentrates valued at $565,000 were shipped from the State.[3] The output for the year was 240 tons, compared to 127 in 1915. The four main producing counties in the State are Cochise, Mohave, Pima and Yavapai.

The Cochise County tungsten camps were particularly active in the first part of the year. The concentrator at the Primos camp was being run day and night, turning out 15 tons of high-grade concentrates per week.[4] The Primos ore consists of both placer gravel and white quartz. In the Dragoon district, huebnerite accompanied by small quantities of scheelite occurs with fluorite in quartz veins cutting granite, and in placers derived from these veins.[5] In the Dragoon Mountains at Russellville, huebnerite and scheelite are found in small quartz veins, cutting a granite stock, which is in the shape of an oval area 4 miles by 2. Every arroyo in these mountains was searched for tungsten placers. In the Whetstone district wolframite veins are found in quartz and granite, with a little scheelite. The American Tungsten Co. purchased the old Euclid wolframite claims 10 miles southwest of Benson, and started erection of a large concentrating plant. The Primos Chemical Co. also owns mines in this district and in the spring of the year 250 men were employed here.

[1] *Eng. Min. Jour.*, Dec. 23, 1916; *Min. Amer.*, May 27, 1916; *Salt Lake Min. Rev.*, Dec. 30, 1916.
[2] U. S. Geol. Surv.; *Min. Jour.*, Feb. 24, 1917.
[3] Frank L. Hess, U. S. Geol. Surv.
[4] *Eng. Min. Jour.*, May 27, 1916.
[5] Charles F. Willis, *Min. Sci. Press*, June 3, 1916.

In the Bower district in the Chiricahua Mountains scheelite occurs in veins with pyrite and chalcopyrite. Other active camps in Cochise County were the Sebring, Draper Co.(Chicago), J. R. Hubbard and M. W. Larson.[1]

Mohave County has two tungsten districts, the Acquarius, about 12 miles from Owens on the Big Sandy River, and the Yucca district, 12 miles east of Yucca. At the Tungsten Mountain claims in the Acquarius district the country rock is chiefly granite, and the ore is in fissure-veins 1 to 3 ft. wide.[2] Wolframite occurs in bands between quartz. In the Yucca district both tungsten and molybdenum occur. A belt of silvery white mica schist is exposed in the flat at the west base of the Hualpai Mountains.[3] Alternating with the schist are limestone and quartz of varying widths. Wolframite with small amounts of scheelite occurs in hard glassy quartz stringers in the schist and at its contacts with the limestone and with the granite on either side of the belt. Copper carbonate and sulphides occur in close relation with the wolframite, but in no case are they intimately mixed with the latter. In drifting on the veins, an increase in copper content is a sign that high-grade tungsten ore is only a few inches away. There are two mills operating in the Yucca district, that of the Yucca Tungsten Mining Co. and that of the Williams Tungsten Co.

In Pima County the district of importance is that of Arivaca, locally called the Las Guigas district. Huebnerite, accompanied by wolframite and a little scheelite, occurs in quartz veins. The country rock is coarse-grained biotite granite, with its accompanying fine-grained acid rock with some diorite dykes, which are intimately associated with the veins and vary from a few inches to 40 ft. in width.[4] The principal shipper from this district is the International Tungsten Co. The company operates a mill producing 20 tons of concentrates per month.[5] The Las Guigas Mining Co. was incorporated to take over the Bent and Sampson claims.

In Yavapai County tungsten was mined in the Tule Creek, Tip Top and Eureka districts. The minerals are huebnerite and wolframite. The Tip Top mine is an old silver mine; the tungsten ore used to be regarded as "black jack" and thrown on the dump.

A little tungsten was also mined in the Globe-Miami district (Powers Gulch Development Co.) in Gila County; in the Cave Creek district (Pittsburgh Tungsten Co.) in Maricopa County; in the Old Hat district of Pinal County, where scheelite occurs with gold and silver;[6] and in the Calabasas and Nogales districts in Santa Cruz County.

[1] *Min. Eng. World*, July 22, 1916.
[2] C. F. Willis, *loc cit.*
[3] Fred. L. Wilson, *Mining and Oil Bull.*, Nov., 1916.
[4] H. H. Taft, *Min. Eng. World*, June 3, 1916.
[5] Hiram Whitcomb, President.
[6] C. F. Willis, *loc. cit.*

California.—California is the largest scheelite producer in the world. The output of 60 per cent. concentrate in 1916 totalled about 2200 tons, which includes some wolframite and ferberite, compared with 1050 tons in 1915.

San Bernardino County.—The remarkable boom and growth of the Atolia district which had started in 1915[1] continued through the first half of the year. The appearance of the tented city of Atolia was pleasantly reminiscent of Tonopah and Goldfield during early days. The town is situated near the boundary between San Bernardino and Kern Counties, about 40 miles west of Kramer, a station on the Santa Fe R. R.[2] The Atolia Mining Co. is the nucleus around which Atolia has grown. This company shipped 1831 tons of scheelite concentrates in 1916.[3] The concentrates averaged 60 per cent. tungstic acid. During the greater part of the year the company's mines and mill were operated on three 8-hr. shifts. Hutchinson describes the milling operation as follows: Primary breaking is done in a Hercules-Blake crusher, while the finer grinding is completed in a Marcy ball mill and Huntington underdriven roller mills. Sand and slime are separated by Dorr duplex classifiers, while Callow tanks are used for dewatering; subsequent concentration is effected by Deister Simplex double-and single-deck tables. The tailing is dewatered in an Oliver continuous filter. The Atolia deposits are in more or less continuous fissures in a granite, and the scheelite occurs mixed with quartz. The veins have been followed to a depth of more than 700 ft. on the dip, and in places are more than 3 ft. wide. In some localities scheelite occurs associated with small basic dikes in granite rock; and in other localities it is found in metamorphosed limestone, at or near contacts. The Mojave Tungsten Co.'s property is located in the Clark Mountain district in San Bernardino County, about 20 miles from Jean, Nev., the shipping point. The ore-bodies are almost wholly wolframite and the claims cover an area of 2 square miles. The property is still in the development stage and the output during 1916 has been but 4 to 5 tons of concentrates per month.[4]

Kern County.—On the Consolidated Mines property near Randsburg a 2-ft. vein carrying scheelite was discovered on the surface immediately behind the mill. The company installed a 40-ton concentrator in connection with the stamp mill. The Rand Minerals Co. near Kernville installed a new mill. The tungsten deposits of Kern County are geologically a part of those of the Atolia district.

Nevada County.—The Grass Valley tungsten district is about 40 miles north of Sacramento. The mineral is chiefly scheelite. The Golden

[1] *Cf.* MINERAL INDUSTRY, **24**, 687.
[2] For full account see C. T. Hutchinson, *Min. Sci. Press*, May 27, 1916.
[3] Communicated, Atolia Mining Co., San Francisco, Cal.
[4] Communicated, Mojave Tungsten Co., 74 Broadway, New York; see also under "Colorado."

Gate company increased the capacity of their mill to 60 tons of ore per 12 hr.

Inyo County.—This county lies about midway between San Bernardino and Nevada Counties. The newly developed tungsten deposits are described in detail by Adolph Knopf of the *Geological Survey.*[1] The deposits, located west of Bishop, although discovered in 1913, were not developed until 1916. The Standard Tungsten Co. acquired the Aeroplane group of six claims and began work on April 7 and by June 7 a 50-ton mill was crushing ore. The company acquired four additional claims and before the close of the year shipped 12 tons of 65 per cent. scheelite concentrates.[2] The Tungsten Mines Co. owns 14 claims which lie north of those of the Standard Tungsten Co. The T. M. C. mill started operating on the first of August with a daily capacity of 350 tons of ore, running 2 to 4 per cent. WO_3. The concentrates averaged 65 per cent. WO_3.[3] The company also has a mine in Arizona near Kingman. The Bishop deposits, like those discovered in Humboldt County, Nevada,[4] belong to the contact-metamorphic class, a well-known source of copper and iron, but not widely recognized as a possible source of tungsten. The Bishop ore consists of scheelite associated mainly with garnet, epidote, and quartz. The ore bodies are from 20 to 60 ft. wide and from 150 to 260 ft. long. The Tungsten Mines Co. mill is described by L. A. Palmer.[5]

Colorado.—The tungsten production of the State of Colorado during 1916 surpassed all previous records. Nearly 4000 tons[6] of 60 per cent. concentrates were shipped; this exceeds by far the production of any other State in the Union, is twice the total production of the entire United States in 1915 and equals the production of Burma, India, heretofore the world's record producer.

Boulder County.—About 90 per cent. of the State's tungsten was mined in Boulder County. The tungsten district is situated about 25 miles northwest of Denver. It is nearly 12 miles long and 7 miles wide. The principal mining centers are Nederland, Lakewood, and Stevens Camp. The entire population of the district was 5000 in 1916 compared with 200 in 1914. The altitude of Nederland is 8237 ft. above sea-level.[7] The higher-grade tungsten ore (ferberite) is usually found in very narrow seams or in comparatively small lenses, involving maximum development work. The most important country rock is biotite-hornblende granite. Most of the mines are found in the granite and the more

[1] *Bull.* 640-L.
[2] Communicated, Standard Tungsten Co., Los Angeles, Cal.
[3] Communicated, Tungsten Mines Co., Los Angeles, Cal.
[4] F. L. Hess, U. S. Geol. Surv., *Bull.* 652.
[5] *Min. Sci. Press*, Sept. 9, 1916.
[6] *Min. Jour.*, Mar. 17, 1917.
[7] For full account of this district see articles by H. J. Wolf and P. P. Barbour, *Eng. Min. Jour.*, July 22, 1916; J. G. Hibbs, *Min. Eng. World*, May 20, 1916; C. T. Kirk, *Min. Sci. Press*, May 27, 1916; E. H. Leslie, *ibid.*, Sept. 2, 1916.

granitic parts of the gneiss. A number of veins follow the dikes of coarse and fine pegmatite. The ferberite occurs in finely crystallized compact masses and also in well-developed crystals; it is frequently embedded in or closely associated with quartz, and this one is commonly called "horn rock" by the miners. The absence of cassiterite, tourmaline, and other common associates of tungsten is noteworthy. Up to the present time the development of the district may be regarded in a general way as somewhat superficial, since most of the mines are less than 300 ft. deep. The Conger shaft (named after S. P. Conger, who discovered the district in 1870) is 1160 ft. deep, the Beddig 600 and the Cold Spring 350 ft.; the other 20 shafts are less than 300. The ore usually runs between 1.5 and 4 per cent. tungstic acid (WO_3).

There were ten concentrating mills operating in the district in 1916. By the end of the year three of these shut down. The larger mills made an average recovery of 89 to 91 per cent. Standard wet concentration methods are used.[1] Abundant electric power is developed from the reservoir of the Colorado Power Co. in the middle of the district. The creek below the dam runs 15 to 20 sec. ft., which is a plentiful supply.[2] Ore running above 0.25 per cent. P or 0.01 per cent. S is not sold. During the year leases were let on every manner of operation, from the raw prospect to abandoned drifts and stopes of the more extensive operations, as well as old dumps and creek beds.

The Primos Chemical Co., the oldest and largest tungsten concern in Boulder County, operates the Conger, Beddig and other tracts. The Wolf-Tongue Mining and Milling Co. operates 15 mines, including the Clyde, Cold Spring and Star. There were 40 sets of lessees at work in the properties in August. The Clyde ore carries from 3 to 4 per cent. WO_3. The vein is alongside a pegmatite dike. The method of mining is similar to that employed in shrinkage stoping. The Vasco Mining Co. operated nine properties. The company has two mills, the Boyd mill at Boulder and the Vasco Mill at Tungsten, Colo., their combined 1916 production amounting to 468 tons of 60 per cent. concentrates.[3] The Clark mill of the Boulder Tungsten Production Co. was completed in January, 1916. It is one of the most modern mills in the district. Its capacity is 30 tons of ore per day. It was designed by Randall P. Akins of the Colorado Iron Works Co. and cost $25,000.[4] The extraction is about 90 per cent. The company operates the Forest Home Group, 1905 Mine, Gold Ribbon, Nancy Henderson, Dillon and Long Shot Group. The total shipments for 1916 amounted to 200 tons of

[1] E. H. Leslie, *loc. cit.*
[2] C. T. Kirk, *loc. cit.*
[3] Communicated, The Vasco Mining Co., Boulder, Colo.
[4] See flow sheet, *Min. Sci. Press*, Sept. 2, 1916.

55 per cent. concentrates valued at $400,000.[1] The Degge-Clark Tungsten Co. of Boulder remodeled the old Colburn mill into a tungsten concentration custom mill. The company operated the Pioneer and Nellie Davis mines and produced about 60 tons of 55 per cent. ferberite concentrates.[2] The Luckie 2 Tungsten Co. erected a 30-ton concentrating mill. Other operating companies in the Boulder district were the Tungsten Metals Corporation, The Intermountain Tungsten Milling, S. A. Grimm & Son, John Duncan, and Eagle Rock.

Other Counties.—In Gilpin County at Rollinsville the Rare Metals Ore Co. built a 100-ton concentrating plant. At Utah Junction, 4 miles from Denver, the company erected a plant for the manufacture of ferro-tungsten, 600 tons annual capacity. In San Juan County, on the other side of the Rockies, several of the known huebnerite veins in the vicinity of Silverton were developed and much prospecting done.[3] In Lake County, near Leadville, scheelite and huebnerite were discovered in the Garbutt and Ibex properties on Breece Hill.[4] The country rock in the vicinity of the deposits includes Weber grit and gray porphyry, and the veins may cut both. The principal minerals in the veins are quartz, pyrite, wolframite and scheelite. Sericite, in parallel growth with quartz, forms films along the fracture walls. The Nonie, Ontario and Capitol claims were worked at from 200 to 250 tons per day, averaging 0.8 oz. of gold and 0.5 oz. of silver per ton besides the tungsten. The wolframite masses contain numerous small grains of pyrite, some of which are intimately intergrown with wolframite. The scheelite occurs in localized aggregates, some closely associated with masses of wolframite, others with pyrite and quartz. In the Garbutt mine the gold values tend to increase with the tungsten value in the vein. Most of the tungsten has heretofore been lost in the slag of the gold smelters. In Park County at Alma rich huebnerite shoots were uncovered in Buckskin Gulch; new discoveries of tungsten were also made in Eagle and Chaffee Counties.

The Tungsten Products Co. and the Black Metal Reduction Co. at Boulder entered the field of manufacturing tungstic acid. The former is turning out 600 lb. of WO_3 daily.[5] Only 0.25 per cent. of the acid is insoluble in ammonia. The product is very low in sulphur and phosphorus, the maximum permissible amount being 0.04 per cent. of each. The Tungsten Products Co. is making tungstic acid and ferro-tungsten, the latter an electric-furnace product.

Connecticut.—The tungsten deposits of North and South America are situated almost exclusively in the Primary Highland, commonly called

[1] Communicated, J. G. Clark, Pres., The Boulder Tungsten Prod. Co.
[2] Communicated, The Degge-Clark Tungsten Co.
[3] See Mineral Industry, **24,** 691.
[4] R. S. Fitch and G. F. Loughlin, *Min. Eng. World,* June 3, 1916.
[5] *Met. Chem. Eng.,* April 15, 1917.

the Pacific Highland in North America and the Andean Highland in South America. There are, however, a number of localities in the Appalachian and Brazilian Highlands that have been commercially worked for tungsten in the past. During the year 1916 the deposits in Fairfield County, Connecticut, and those of Nova Scotia—New Brunswick—were unusually active again due to high prices for the mineral.

The Connecticut tungsten district consists of 56 acres located near Long Hill and Trumbull in the Shaganowaump Mountains. The mineral is scheelite (at Trumbull also wolframite) occurring as a blanket vein 18 to 24 in. thick all of which is of a milling grade. There also appears to be a pegmatite dike varying from 3 to 5 ft. in width and extending over 25 acres, which is said to carry ore of a milling grade. The last company, the Tungsten Mines Co., erected a modern mill in an experimental way and produced about 5000 lb. of concentrates running about 70 per cent. tungstic acid. Unfortunately the mill was destroyed by fire and no new one has been built since.[1]

Previous to the outbreak of the European war the main output was sold to Krupp at $450 to $650 per ton of 60 per cent. concentrates.[2]

Idaho.—About 45 tons of scheelite and wolframite concentrates were produced in this State during 1916 compared with 25 tons in 1915. Tungsten occurs in widely scattered districts over the entire State. Important districts are near Murray, near Patterson in Lemhi County, and near Corral in Blaine County.

The occurrence of scheelite in the Cœur d'Alene region, so far as known, is wholly confined to slate. The ore is found in quartz veins associated with gold, silver, pyrite, chalcopyrite, sphalerite, galena, magnetite and siderite.[3] The scheelite occurs in lenses, stringers and disseminated grains, and it is known to persist as deep as the deepest workings (for gold), 900 ft. below the surface.

Nevada.—Since 1915 Nevada has been one of the important tungsten States in the Union. Although the metal has been known to occur in the State for a number of years, it was not until the large war orders of 1915 brought the price from $7.50 up to $43.00 per unit of WO_3 that the tungsten districts of the State were developed. Tungsten has become second in importance to copper in the State. According to Frank L. Hess of the U. S. Geological Survey 461 tons of 60 per cent. concentrates, valued at $1,432,000, were shipped from Nevada in the first 6 months of 1916. The year's output of the State is estimated at 700 tons compared with 55 tons in 1915. Discoveries of tungsten ores in the first part

[1] J. L. Danziger, Brooklyn, N. Y.

[2] W. H. Hobbs, The Old Tungsten Mine at Trumbull, Conn. U. S. Geol. Surv., *22nd Annual Rept.*, part 2, 1910. U. S. Geol. Surv. *Bull.* 213, 1903.
Adolph Gurlt, *Trans. Am. Inst. Min. Eng.*, **22** (1894).

[3] *Min. Sci. Press*, Jan. 27, 1917.

of the year caused veritable stampedes to several localities, notably in the Snake Range region east of Ely; in the Mina district in Mineral County; at Toy in Humboldt County and at points in Esmeralda, Nye and Eureka counties.[1]

White Pine County.—The activities in this county are fully described by Fred. L. Miner.[2] The proven tungsten belt extends 70 miles in length along the Snake Range near the Utah line. The mineral occurs in the form of huebnerite and scheelite in white quartz veins in granite, quartzite and lime. In contradiction to popular ideas, huebnerite and scheelite are found associated together in some veins. In one instance a large cube of huebnerite was found inside a crystal of pure scheelite. New valuable tungsten finds were made on both sides of the Snake Range all the way from the Minerva district, at the southern end, to Tungstonia, near Aurum. Among the largest operators is the U. S. Tungsten Corporation, which controls 1600 acres of lode and tungsten placer claims. Fifteen veins were under development, the Hub and Big Chunk veins being the biggest producers. The 1916 output was about 200 tons of concentrates, valued at $688,400, which was largely contracted for by the Midvale Steel Co. The company has a large mill at Osceola, 46 miles from Ely. Part of the concentrates were converted into ferrotungsten in the new electric-furnace plant at Philadelphia.[3] The Independent Tungsten Co. erected a 30-ton mill at Scheelite, which is about 2 miles north of Mount Wheeler. Tungstonia is probably the richest district in the entire Snake Range zone. The Tungstonia Mines Inc. property promises to be one of the largest and steadiest producers in this country. The country rock is granite, heavy in biotite and muscovite mica. According to Alexander R. Shepherd, President of the company, there are eight veins uncovered which are all fissure veins with quartz filling. Huebnerite and pyrite are the principal minerals. The veins vary in width from 2 to 30 ft. and are traceable for several thousand feet on their strike. About 30 tons of 65 per cent. concentrates were shipped and the outlook for 1917 is most encouraging. About 50,000 tons of ore is developed. The property of the Consolidated Tungsten Co. is located in Williams Creek Gulch near Scheelite; it includes the Big Four vein, which is 10 to 20 ft. wide, the Gem vein on the south side of Williams Creek, the Doseoaris and Outlook veins. The mineral is chiefly huebnerite. A few miles south of Williams Creek Gulch, the formation changes to limestone and the ore in the veins is scheelite of the pearly gray variety. Here at Camp Minerva the Nevada Scheelite

[1] R. L. Richie, *Min. Sci. Press*, June 3, 1916.
[2] *Min. Eng. World*, April 29, 1916; June 10, 1916; *Salt Lake Min. Rev.*, April 30, May 30, 1916.
[3] Communicated, John Borg, New York City.

Co. operated the Scheelite Chief, Oriole and Everett veins. The Scheelite Chief was worked for silver in the 70's.

Other active mines in the county were those of the Apex group (Chas. Osterland) which adjoins the Shepherd or Ophir group at Tungstonia; at Big Wash, on the east side of the Snake Range, the mines of Chapman and Taylor; and the mines of the Salt Lake-Tungstonia Mines Co. near Tungstonia.

Humboldt County.—Humboldt county in the northern part of the State experienced a marked revival in mining industry; silver, gold and tungsten were again produced in substantial quantities. The Humboldt County Tungsten Mines and Mills Co. operated the Ragged Top Mines, located 10 miles west of Toulon on the Southern Pacific R. R. in the Lovelock district. The mineral, scheelite, occurs in contact-metamorphic zones, garnetiferous limestone, limestone and shale in contact with grano-diorite. At the Eureka mill in Utah 1726 tons of dry ore was concentrated, yielding 50,002 lb. of 60 to 70 per cent. WO_3 at an average recovery of 60.5 per cent. At the Toulon, Nev., mill 1715 tons of ore produced 25,473 lb. of 60 to 70 per cent. concentrates, at an average recovery of 72.5 per cent. The total 1916 output of the Ragged Top mines was therefore equivalent to about 41 tons of 60 per cent. concentrates.[1]

South Dakota.—At Hill City, in Pennington County, on the C., B. & Q., the Hill City Tungsten Production Co. began operations in May, 1916. The mineral is wolframite associated with cassiterite, very much like the deposits in Cornwall, England. The double feature of tin and tungsten recovered in the same mill gives the enterprise a strong bid for stability.[2] The mine from which ore was taken was developed by the old Harney Peak Tin Co. (1890). The ore-body ranks as commercial only because the cost of the full development work, including equipment, did not have to be incurred by the new company. Besides the tin and the tungsten a mica by-product is recovered that contributes to the profitableness of the mine. The ore-bodies fall into three distinct types: first, pegmatite dikes; second, true quartz fissure veins; third, a distinct type of quartz vein, lenticular, with both ends of the vein in sight. The quartz lenses are either barren or carry tungsten only. Most of the Hill City tungsten (wolframite) occurs in the pegmatite dikes. The tin ore-shoots in the dikes extend across the full width of the dikes, being richest on the foot-wall but uniform in others. The best ore is usually accompanied by an increased mica content (up to 20 per cent.). Tung-

[1] Communicated, Humboldt County Tungsten Mines and Mills Co., Lovelock, Nev.
[2] John Bland, *Min. Sci. Press*, Mar. 31, 1917.

sten custom ores constituted half of the basis of the operations of the Hill City mill.[1]

The largest tungsten producers of the State were the two gold mines, Wasp No. 2 and Homestake.[2] A new record was set in the value of tungsten ores in the Black Hills when on the 17th of March, 1916, the Wasp No. 2 Mining Co. sold 19 tons of mixed grade ores for $83 per unit. The carload was valued at over $90,000. A few grades of hand-sorted ore and three grades of concentrates—35, 45, and 65 per cent.—made up the lot. This shipment was the result of a little more than a month's actual operation of the concentrating plant.[3]

The American Tin and Tungsten Co. was organized in the fall of the year.

The total production of the State is estimated at 200 tons in 1916, compared with 140 tons of concentrates in 1915.

Other States.—The White Oaks Mines, Consolidated, recovered considerable quantities of tungsten (huebnerite) at the White Oaks gold mines in Lincoln County, New Mexico. Small shipments of ore were made from various points in the Cascade Mountains in Washington and a new mill erected on Tungsten Mountain, 35 miles northwest of Oroville.[4] The mineral at Tungsten Mountain is wolframite; the mine is owned by the Tungsten Mines Co. In July, 1916, tungsten ore was discovered in Utah in the Uintah Basin near Linwood, close to the Wyoming border.[5] Tungsten mining was started as a new industry at Silver mine, Madison County, Missouri.

UNITED STATES PRODUCTION ACCORDING TO STATES
(Short tons of 60 per cent. concentrates)[6]

	1915.	1916.		1915.	1916.
Alaska	2	50	Missouri	....	2
Arizona	127	240	Nevada	55	700
California	1,050	2,200	New Mexico	45	15
Colorado	963	4,000	South Dakota	140	200
Connecticut	1	3	Utah	3	6
Idaho	25	45	Washington	2	8
			Totals	2,413	7,469

Tungsten in Foreign Countries

Canada.—Tungsten deposits were worked experimentally near the banks of the Miramichi River, New Brunswick. A shaft 50 ft. deep was

[1] This mill is fully described by John Bland, *loc. cit.*
[2] See Mineral Industry, **24**, 695.
[3] *Min. Sci. Press*, April 8, 1916.
[4] Frank L. Hess.
[5] *Salt Lake Min. Rev.*, July 30, 1916.
[6] Statistics based on reports by Frank L. Hess of the Geol. Surv. and upon reports received from the individual tungsten producers.

sunk and a concentrating plant of a daily capacity of 20 tons of ore was installed. About 30 tons of concentrates were turned out.[1]

Nova Scotia shipped about 400 tons of concentrates. The most important tungsten locality is in Halifax County. The mineral is chiefly scheelite.

South America

Argentina.—The only mining of consequence in Argentina in 1916 was for tungsten and petroleum. Tungsten was mined chiefly in the Province of San Luis, but also in San Juan and La Rioja. About 700 metric tons of concentrates were produced.[2]

The Director General of Mines, Geology and Hydrology of Argentina issued a report on the deposits of tungsten in the country.[3] The mineral is chiefly wolframite, found mostly in veins of quartz with mica. Important mines are located on the east side of the Sierra of San Luis, west of the village of Dolores, near the Concaran station of the Pacific Railway. The Hansa Sociedad de Minas resumed operations of their San Luis deposits in the latter part of 1915, they having been suspended soon after the outbreak of the war.[4] During 1916 the Hansa Mines were working at full capacity, about 50 tons of concentrates per month, the entire product being contracted for in the United States.[5]

Bolivia.—The great tungsten boom of the spring of 1916 was particularly marked in the tungsten mines of the Oruro district in Bolivia. Tungsten practically displaced rubber as the "black gold" of South America.[6] Up to the latter part of April the ore producers were clearing over $200 per cwt. of concentrates. The enhanced prices caused the opening up of large deposits in the northern part of the country. Numbers of miners were drawn away from the tin deposits. It was the nearest approach to a big mining strike in West Coast mining camps within the last 10 years.

During the first 4 months the four producing Departments turned out 792 metric tons valued at about $3200 per metric ton. In the remaining 8 months the production fell off to almost nothing. The total year's production was 920 metric tons (60 per cent. basis) compared with 793 tons in 1915 and 276 tons in 1914. Of the 1915 production, 436 tons came to the United States and 357 tons to Great Britain. Oruro has enjoyed preëminence among the departments as the largest producer, furnishing about 70 per cent. of the total. About 20 per cent. was furnished by La Paz and the remainder by Potosi.[7]

[1] *Comm. Rept.*, Aug. 19, Oct. 28, 1916.
[2] *Eng. Min. Jour.*, Jan. 6, 1917.
[3] *Comm. Rept.*, July 14, 1916.
[4] *Comm. Rept.*, July 13, 1916.
[5] *Min. Eng. World*, July 1, 1916.
[6] *Comm. Rept.*, April 18, 1917.
[7] W. F. Montavon, *Comm. Rept.*, Aug. 7, 1916. The important mining centers in Bolivia are enumerated in *Min. Jour.*, Aug. 26, 1916, p. 584.

The exports were somewhat less than the production. The United States took 75 per cent. and Europe 25 per cent.

Chile.—Sr. I. D. Ossa describes in detail the deposits in the Department of Arica in his report issued in the fall of the year.[1] The deposits are about 56 miles from Arica City and not far from the River Lluta. This river has sufficient volume and fall to generate power to work the mines and mill. At present all work is being done by hand; the wages per day are: for drillmen, 5 pesos; ore breakers, 4 pesos; and sorters, 4 pesos. The deposits of copper and tungsten are located at about 2 miles above sea-level. They are connected with the headquarters at Cupane by a Llama path 7 km. long. The total cost of transport to Arica including all handling was 56 Chilean dollars per ton. No output figures have been published; probably totaled less than 100 tons of concentrates.

Peru.—Peru was the third largest producer of South America. The figures for 1916 reached almost 400 tons of concentrates, compared with 371 tons in 1915 and 196 tons in 1914.[2] During the first 3 months of 1916, 70 tons of concentrates were exported from Salaverry to the United States and England. A company in Lima entered upon a contract for delivery of 30 tons of concentrates per month.

Tungsten was first discovered in Peru associated with gold in a mine in Lircay, Ayacucho, and later on in considerable quantities in the mountain region of Pelagatos, in the Province of Santiago de Chuco, where there exist to-day several valuable mines. The mineral found in Lircay is wolframite and that found in the north is principally huebnerite. The three principal mines are owned by Peruvians. During the summer of 1916, Col. Dogny of the French army visited the tungsten-producing areas in the interest of the Creusot factories of Schneider & Co. (France).

In December, 1916, an option was granted to English interests over the Huaura wolfram deposits in the Province of Ancachs. These mines are situated on a spur of the Pelagatos Mountains at an altitude of from 13,000 to 14,000 ft. above sea-level. They were opened up in 1911.[3] Tarnawiecki considers these deposits the largest in the world, with a probable capacity of 6000 to 7000 tons of concentrates per annum.

On Nov. 14, 1915, the new Peruvian Mining Law went into effect, providing an export tax on nearly all minerals shipped from the country.

Europe

Austria and Germany.—M. Souchinsky[4] estimates the tungsten production of Austria-Germany at 200 tons per annum since the outbreak

[1] *Min. Jour.*, Dec. 16, 1916.
[2] W. W. Handley, *Comm. Rept.*, Sept. 12, 1916.
[3] *Min. Jour.*, Mar. 3, 1917; also Tarnawiecki, *Min. Jour.*, July 8, 1911.
[4] *Min. Jour.*, Dec. 16, 1916.

of the war. This estimate is probably too low. Since 1913 no authentic figures have been published. Previous to the war, Germany derived most of her supply from abroad. The German official figures for 1913 are 4615 tons imported and 777 tons of concentrates exported. At that time Germany was supplying the English steel works with practically all of the metal and ferro-alloy required.

Germany's important tungsten district is located in the Erzgebirge, a chain of mountains between Saxony and Bohemia.

England.—In 1916 England controlled about two-thirds of the world's output of tungsten. The extraction of the metal from the concentrates was carried out on a large scale at Widnes, Luton and Sheffield. Previous to the war this industry was monopolized by the Germans. The High-Speed Steel Alloys, Ltd., was established at Widnes in response to an urgent need to insure an adequate supply of metal and ferro-tungsten for the steel works. The company was capitalized by 31 of the largest steel manufacturers in the British Isles.[1] The Continuous Reaction Co. completed new works at Hyde in Cheshire. The Thermo-Electric Ore Reduction Corporation's plant is located at Luton. This plant is successfully treating tin-scheelite ores with a recovery of both products. The interests connected with the company are spending large sums on mines abroad to insure a supply of 4000 tons of 65 per cent. concentrates a year.[2] The reduction plant capacity in England to-day is about twice the amount of ore readily obtainable.

Wolfram ore is mined in limited quantities in Cornwall and Cumberland. The tungsten is a by-product of the tin industry.[3] Considerable research was carried out by the Institution of Mining and Metallurgy on the separation of tin and tungsten commercially. The working of the Cornish mines was handicapped in a dozen different ways, scarcity of labor, low rates for product, high cost of living, etc., and the output was lower than was expected. The total concentrates produced from the British Isles mines was about 200 tons. The St. Ives Consolidated at Camborne was acquired by the Thermo-Electric Ore Corporation, Ltd. At Giew, Frank's shaft was sunk 184 ft. Good values were met with, the lode producing 80 lb. per ton (vanning assay) over a width of 5 ft. The Parc-an-Chy mine, of the Cornish Wolfram Mines, Ltd., is located near Redruth on the main line of the Great Western Railway. The lease extends over 70 acres covering three known lodes for about 1700 ft. The country rock is a compact micaceous granite in contact with an overlap of clay slate.[4]

[1] *Min. Sci. Press*, Jan. 6, 1917.
[2] *Min. Jour.*, **114**, 797.
[3] Mineral Industry, **24**, 698.
[4] *Min. Jour.*, Mar. 17, 1917.

In September the Minister of Munitions fixed the price of ferro-tungsten at 5s. 6d. per lb. of tungsten-content and tungsten powder at 6s. 3d. per lb. of tungsten-content.[1] In December an embargo was placed on all classes of tungsten ores.[2]

France.—Wolframite with cassiterite occurs in the "porcelain center," Haute Vienne, and scheelite occurs at Meymac and Framont in the Vosges mountains. The output of the entire republic has been at the rate of 200 to 300 tons of 60 per cent. concentrate per annum; however, no official reports have appeared since the outbreak of the war. M. Jules Huré made a very careful survey of the Haute Vienne districts in the early part of 1916.[3] The tungsten area extends over 7.412 hectares near Vaulry and Cieux. In the Poudrière veins the wolframite and cassiterite are accompanied by some scheelite and molybdenite. The gangue is quartz, iron pyrites and mispickel. In the Jouhe deposits the wolframite is very often so finely divided and intimately mixed with the quartz that concentrating is attended with difficulty. In the Lagarde veins cassiterite predominates.

Portugal.—Portugal is the largest producer in Europe.[4] The output for 1916 is estimated at 1700 tons of 60 per cent. concentrates. The Wolfram Mining & Smelting Co. is a London company working mines at Silvares. The monthly production was about 30 tons. The report for the year ending Sept. 30 shows sales amounting to £52,458 and a dividend of 15 per cent. to the stockholders.[5]

Russia.—According to M. Souchinsky of the Russian Geological Committee[6] a tungsten deposit was developed at Baevke in the Urals in the Province of Perm. The output did not exceed 1 ton of wolframite per month. In Asiatic Russia tungsten is found in the Nertschinsk Mountains to the east of Lake Baikal: the total output was but 6 tons per month. The total output of the Empire amounted to about 50 tons of 60 per cent. concentrates.

Spain.—Under the stimulus of high prices and big war demands the tungsten production of Spain reached a record output of 511 tons in 1915, valued at $43,664 at the mines. Three deposits were worked. Those of Zamora and Salamanca, on the Portuguese boundary, produced 333 tons of concentrates. The mineral is a tin-bearing wolframite. In the northwest, Coruña, Orense and Pontevedra produced 150 tons, mostly alluvial. Badajos returned 25 tons and 2 tons was derived from the province of Almeria in the southeast.[7]

[1] *Comm. Rept.*, Sept. 21, 1916.
[2] *Comm. Rept.*, Dec. 22, 1916.
[3] *Bull. de la Soc. de l'Industrie Minérale*, **9**, 99–115.
[4] See MINERAL INDUSTRY, **24**, 698.
[5] *Min. Mag.*, Feb., 1917.
[6] *Min. Jour.*, Dec. 16, 1916.
[7] *Min. Jour.*, Dec. 16, 1916.

The tungsten deposits of Malaga were investigated by French companies and at the end of the year 1916 there were good prospects of important contracts.

Asia

Burma.—The Burma tungsten belt, which is one of the richest in the world, has for a number of years turned out record tonnages. The belt is about 56 miles in length and 7 miles wide. There are now four important tungsten districts, the Tavoy and Mergui districts being the principal centers of production. In the Thaton district the mines have been worked on a commercial scale only since 1914. The fourth important district is in the Southern Shan States where tungsten is obtained as a "by-product" of the tin ore mines (*q.v.*). In the Tavoy district the wolframite occurs in fissure-veins traversing the granite and associated argillaceous rocks.[1] Ground sluicing is the method of extracting most widely employed, but the hydraulic system is sometimes used and actual mining in the veins is on the increase. There are now about 50 tungsten-producing mines in Burma.

Toward the close of the year wolfram-bearing quartz lodes were discovered on three concessions in the Pe district.[2] The Geological Department reported that the district consisted of granite with a band of sedimentary rocks of the Mergui series running up the Pe Chaung and small cappings of the same rocks above the granite at high levels. The lodes usually occurred at the junction of the granite with the sedimentary rocks.

Every effort was made in 1916 to meet the Home Government's urgent war demand to bring the yield up to 500 tons of wolframite per month. Thousands of coolies were imported, new roads constructed and concessions liberally awarded. Nevertheless the methods of mining and milling and the means of transportation are still very primitive and crude. The imported Chinese coolies proved a failure with few exceptions.

Consul Dorsey of Rangoon reported that 3806 metric tons of 65 per cent. tungsten concentrates were exported from Burma in 1916 as compared with 2661 tons in 1915. The increased production was due largely to higher rates being paid the old miners, to their working double shifts, and to the fact that a number of new areas were opened up.[3] The "Defence of India Wolfram Rules of 1915" were amended in the spring of the year and regulations governing the mining of wolframite were made more stringent.

[1] Consul W. R. Dorsey, Rangoon, *Comm. Rept.*, Dec. 27, 1916.
[2] *Min. Jour.*, Feb. 17, 1917.
[3] *Min. Jour.*, **114,** 363.

Most of the concentrates shipped to England contained tin. There was an urgent demand for magnetic separators, but not until the close of the year was the first separator installed near Rangoon. This was furnished by the High-Speed Steel Alloys, Ltd., an organization composed of 31 of the biggest steel manufacturers in the British Isles. They opened up an office and a large laboratory in Tavoy, Burma.[1] The General Manager is Wm. R. Jones, D. Sc., formerly assistant geologist in the Federated Malay States. The organization consumes more than 80 per cent. of the concentrates imported into the British Isles. (See under *England*, above.)

Federated Malay States.—The British Government took over the whole output of tungsten ores in 1915 and fixed the price at $13.37 per unit of tungstic acid.[2] The F.M.S. Government did all it could to stimulate the production of ore and remitted local export duty and offered State land free of premium to those who desired to work the same for tungsten.

In the spring of the year J. B. Scrivenor, Geologist, Bata Gajah, presented to the Federated Malay States Chamber of Mines a detailed account of the occurrence of tungsten in the States.[3] In this report it is pointed out that in the F.M.S. a large proportion of the tungsten minerals is won from detrital material and is mixed with cassiterite. At Bukit Rumpian in Perak are some of the best-known lodes. Here the country rock is tourmaline-granite and is traversed by small quartz veins carrying cassiterite and wolframite. At Tronoh wolframite was found in 1915 in small quartz veins traversing weathered shales close to granitic intrusions. In Selangor practically all the wolfram-tin ore comes from places where there is a contact of granite and schist. The quartz veins, where traversing schist, contain fairly pure wolframite. On the contact of granite and schist the same veins carry mixed ore, and where they continue into granite they get richer in tin and poorer in tungsten. This supports the idea of the cassiterite being precipitated at a higher temperature than the wolframite. Scheelite is found at Kanching and near the Batu Caves. Most of the scheelite produced in Selangor in 1915 came from Kanching. In the Raub gold mines in Pahang scheelite is occasionally found in the lodes.[4] Most of the F.M.S. tungsten ore is of low grade.

According to W. Eyre Kenny, Senior Warden of Mines, the exports of concentrates in 1915 were 400 tons to Great Britain and 183 tons to France compared with 527 tons to Germany in 1913 out of a total of 682 tons. The F.M.S. production in 1915 amounted to 334 metric

[1] *The Far Eastern Review*, Jan., 1917.
[2] *Comm. Rept.*, Nov. 3, 1916.
[3] *Min. Jour.*, **114**, 384, 406, 433.
[4] Scrivenor, *Min. Mag.*, **15**, 347.

tons of 60 per cent. concentrate. About 250 tons were imported, treated, and re-exported.[1]

Japan and Korea.—The tungsten mines of Japan proper are the Kiwada mine in Yamaguchi Ken, with a production of 25 to 40 tons of tungsten ore per month; the Taketori mine in Ibaraki Ken, which produces 10 to 11 tons per month; and several small mines, with a combined production of 75 tons of ore per month. The total output of Japan proper for 1916 totalled 450 tons of 60 per cent. concentrates, being largely exported to the United States.[2]

During the course of 1916 Chosen (Korea) showed a decided growth in industrial and commercial activity. Due to the urgent demands, the natural resources of the Peninsula were rapidly and systematically developed. Chosen produced approximately 670 metric tons of 60 per cent. concentrates during 1916, a 100 per cent. increase over 1915. The output was valued at nearly $1600 per ton.

A new ordinance (war measure) was passed, which became effective July 29, 1916, according to which no tungsten or tungsten ores were to be exported from Japan without a special permit from the Minister of Agriculture and Commerce. The price of tungsten concentrate in July was 40 yen per unit f.o.b. Yokohama. Japan also imported small tonnages from Manchuria. The tungsten deposits are in the Chin Chow district of the Kwangtung Leased Territory in southern Manchuria.[3]

The total output of Japan, Chosen and Manchuria amounted to 1150 tons of 60 per cent. concentrates in 1916, more than double the output of 1915.

French Indo-China.—Tonkin exported to France 250 tons of tin-tungsten ores in 1916 compared with 397 tons in 1915 and 216 tons in 1914.

Siam.—Siam's tungsten output increased from 4517 piculs in the fiscal year 1915 to 7128 piculs in 1916, the fiscal year ending March 31.[4] This corresponds to approximately 297 and 468 metric tons of 60 per cent. concentrate, assuming that the Siam concentrates ran, as usual, 65 per cent. WO_3. The entire amount was mined in the district of Nakawn Sritamarat, in the Siamese Malay States, where the producing area increased and with the continued high prices a still larger output may be anticipated. In the district of Trang, in the same States, scheelite was found and the deposits developed on a small scale.

New and important tungsten areas were opened up along the Royal Siamese Southern Railway. The deposit, both lode and alluvial, extends over several square miles, and has the rare advantage of an inexhaustible

[1] *Min. Jour.*, **114**, 840.
[2] M. D. Kirjassoff, *Comm. Rept.*, Aug. 26, 1916, and Feb., 1917.
[3] J. R. Arnold, *Comm. Rept.*, Mar. 27, 1917.
[4] Carl C. Hansen, *Comm. Rept.*, Mar. 24, 1917.

supply of water running through the centre of the property. The claims are controlled by a British syndicate.

During the fiscal year 1916 the shipments to the United States amounted to 54 tons of 60 per cent. concentrates valued at $46,330, as compared with 27 tons valued at $12,852 in 1915.

Australia and New Zealand

Queensland.—According to the *Queensland Government Mining Journal* every effort was made to put the tungsten mining of Australia on a sound commercial basis. Labor is scarce and very profitable veins have not as yet been uncovered, although the prospects are in many instances exceptionally promising. The two important tungsten districts are the Chillagoe gold field and the Etheridge district. In the latter the predominating mineral has been molybdenite; tungsten and bismuth are by-products. The richer district is in the Chillagoe field. Tungsten associated with molybdenum and bismuth is not found to any extent in defined lodes or fissures. The ore-shoots are often erratic in their course and present faults and pinches in a manner most exasperating to the miner. Mining proper as practiced on well-defined lodes is unknown here. A number of the shafts are 300 and 400 ft. deep. In the fall of the year the Thermo-Electric Ore Reduction Corporation of Luton, England, acquired all the rare metal mines at Wolfram Camp in the Chillagoe Field, including the Murphy & Geaney and Leisner's Wolfram Block.[1] This new company expects to bring the production up to 1000 tons of concentrates per annum. The company further arranged to transfer to Wolfram Camp, Queensland, the entire plant of the Giew mine, Cornwall, England. The production of Queensland for 1916 is estimated at 800 tons (60 per cent.) as compared with 640 tons in 1915.

New South Wales.—An important tungsten discovery was made near Booroowa.[2] The ore has been proved on the surface for a distance of 600 by 210 ft., and to a depth of 35 ft. The wolframite is associated with magnetic iron ore. The mine is being worked as an open-cut; it has an ample water supply and is accessible to the railway. The total output of New South Wales in 1916 was about 125 metric tons of 70 per cent. concentrates compared with 83 tons in 1915.[3]

Northern Territory.—T. G. Oliver, Director of Mines in Northern Territory, reported a new discovery of wolframite at Hatches Creek. The proved tungsten area extends over 8 square miles. About 100 tons of concentrates valued at $800 per ton was turned out before the close

[1] *Min. Jour.*, Dec. 23, 1916.
[2] *Min. Jour.*, Mar. 10, 1917.
[3] *Min. Jour.*, **114**, 597.

of the year. Victoria produced about 20 tons in 1916, compared with 14.5 tons in 1915.

New Zealand.—C. W. Gudgeon describes the scheelite deposits of Otago Province, South Island.[1] The mineral has been found in many parts of the province but only in two districts have the operations been on a commercial scale. One of the districts is at Glenorchy, Northwest of Dunedin, and the other is at Macrae's Flat about 50 miles north of Dunedin. At the Glenorchy mine scheelite is more important than the gold produced. The Golden Point mine at Macrae's Flat was started as a gold producer in 1891. A few years later its scheelite was being shipped to Germany. The scheelite is found in quartz veins traversing mica schists of probably Devonian age.[2] At Macrae's Flat the veins are of the bedded type and at Glenorchy of the fissure type. Below the zone of oxidation the scheelite is associated with pyrite and arsenopyrite. At the Golden Point mill the oxidized ore is crushed to 30-mesh, passed over amalgamating tables, then over concentrating tables to remove the scheelite, the sand tailing treated with cyanide, and the slime tailing stored. With pyritic ore the concentrate is given a magnetic roast and thence passed through a Wetherill separator. The gold runs 2.5 oz. per ton of first concentrates.[3] According to Consul General Alfred A. Winslow, the output of New Zealand in 1915 was 194 metric tons of 72 per cent. concentrates. The price in 1916, fixed by the imperial government, was £2 15s. per unit delivered at London or Liverpool, the scheelite concentrate to contain not less than 65 per cent. WO_3.

Africa

Rhodesia.—Wolframite was found on the Sabi River, but its most important known occurrence in Rhodesia is in the Umzingwane district. Here it occurs in pegmatitic dikes. Extensive sampling with trial washings was made on a bed of many thousand tons of rubble, but the grade was found to be just too low for profitable working. Scheelite is widely distributed in small quantities in the gold reefs of the country. A promising prospect was developed near Que Que. At the Scheelite King Mine, situated 9 miles west of Gatooma, the mineral occurs in lumps in a large quartz reef associated with a mass of fine granite. The output of the mine amounted to 46.5 tons.[4]

German Southwest Africa.—At Nakeis a number of sub-parallel quartz veins carrying wolframite were opened up during the last few years, but

[1] *Proc. Australian Inst. Min. Eng.*, **21,** (1916); *Min. Mag.*, **115,** 103.
[2] A. M. Finlayson, *Trans. New Zealand Inst.*, **40.**
[3] *Min. Mag.*, **15,** 104.
[4] *So. Afr. Min. Jour.*, **26,** 487.

have proved to be too low-grade to warrant exploitation. The wolframite is accompanied by chalcopyrite and in the marginal portions of the so-called Main Lode molybdenite in small flakes is also present.[1]

In 1907 the output of all of Africa amounted to 211 tons of concentrates, but since then the production has been practically negligible.

The World's Output of Tungsten Ores

The following table shows the production of tungsten ores in all of the important tungsten states of the world. Compared with 1915 the total world's tonnage in 1916 showed an increase of 60 per cent.

PRODUCTION OF TUNGSTEN ORES
(Metric tons; 60 per cent. WO_3)

Country.	1906.	1912.	1913.	1914.	1915.	1916.
North America:						
United States	844	1210	1397	900	2120	6790*
South America:						
Argentine	300	638	539	394	171	700*
Bolivia	70	497	564	276	793	920*
Peru	...	214	300	196	371	400*
Europe:						
England	276	193	182	205	360	350*
France	20	230	245*	200*	200*	200*
Germany-Austria	60	167	150*	220*	250*	300*
Portugal	579	1330	800	967	1400*	1600*
Spain	200	169	150	84	511	600*
Asia:						
Burma	...	1905	1732	1868	2883	4123
Siam	...	108	281	30	297	468
Japan	40	205	297	195	439	1150*
Australasia:						
Queensland	800	860	543	435	640	800*
New South Wales	250	271	209	220	100	146*
New Zealand	125	165	270	250	249	300*
Total world production	4000	8780	10,000	8000	12,000	19,000

Statistics reported by F. L. Hess of the U. S. Geological Survey and foreign consuls.
* Estimated.

Technology

The Soda Process.—The ore is fused with sodium carbonate, leached, filtered, and the filtrate treated with muriatic acid. Yellow WO_3 is precipitated; after filtering the oxide is reduced to metal with carbon, aluminium or hydrogen.[2] Stress is laid on the removal of those impurities, such as phosphorus and sulphur, which are injurious to steel.

Ferro-tungsten.—Within the last two years a number of large ferro-tungsten plants have been built in this country and England. The Hudson Reduction Co., Latrobe, Pa., operated in 1916 33 electric smelting furnaces for both the alloy and metal.[3] The Primos Chemical Co. greatly increased its capacity; the Chemical Products Co. completed a

[1] *So. Afr. Min. Jour.*, July 1, 1916.
[2] For further details see *Min. Sci. Press*, Jan. 6 and Jan. 20, 1917.
[3] *Iron Age*, Sept. 7, 1916.

large tungsten reduction plant near Washington, designed particularly for the treatment of lower-grade concentrates; the Tungsten Products Co. of Maryland began operating a new plant early in January, 1917, for making ferro-tungsten, using small electric furnaces;[1] the Manhattan Reduction Co. also produced metal. In France there are important works, *e.g.*, those of Girod, Schneiders, Chamoux, Keller and Leeux, and the Froges and Giffre works. In England, the Thermo-Electric Co. at Luton, the High-Speed Steel Alloys, Ltd. at Widnes, the Continuous Reaction Co. at Hyde, the British Thermit Co. at Garston, and a number of others.

Magnet Steel.—Since the outbreak of the war, Sheffield has specialized in the manufacture of magnet steel for magnetos, etc.[2]

High-speed Steel.—The composition of German high-speed steel is given as follows:[3] C, 0.45 to 0.85; Si, trace to 0.20; Mn, 0.10 to 0.50; W, 8.00 to 18.00; Cr, 2.50 to 6.50; Mo, 0.00 to 2.50; V, 0.00 to 1.50; Co, 0.00 to 5.00. The steels are forged at temperatures above 1000° C. and annealed by prolonged heating at 800°. The hardening methods depend upon the composition and the purpose to which the steel is to be put.[4] Strenuous efforts were made to replace the tungsten in the high-speed steel by molybdenum or other metal. Canada put through a series of tests on molybdenum steels; J. M. Flannery took out a number of patents on uranium steels.[5] The steels were tested and very favorable results obtained. The Physikalisch Technische Reichsanstalt of Germany reported on investigations made on chromium steels, concluding that carefully prepared chromium steel is a suitable substitute for tungsten steel.[6]

Whereas in the wars of the past brass and lead were, next to steel, the most important "martial metals," to-day tungsten alloyed as high-speed steel is the dominating factor. To deprive a nation of tungsten is to cripple its military power, and its industrial power in times of peace.

New Applications of Tungsten.—Probably the most important new application is the use of tungsten metal as a catalyser for the production of ammonia from atmospheric nitrogen and hydrogen. Patents were granted to Carl Bosch and Alwin Mittasch.[7]

J. B. Scrivenor[8] gives a good account of methods of detecting tungsten. A good description of the metal is published by J. F. Lilly.[9] The produc-

[1] *Iron Age*, Feb. 8, 1917.
[2] *Electrician*, Jan. 19, 1917.
[3] *Elektrotechn. Rundschau*, through *Iron Age*, Nov. 16, 1916.
[4] *Iron Age, loc. cit.*
[5] U. S. Patents, 1,210,625; 1,210,626; 1,210,626.
[6] *Elektrotechn. Zeitsch.*, Nov. 2, 1916.
[7] U. S. Patent, 1,175,693.
[8] *Min. Jour.*, June 3, 1916.
[9] *Markets*, June 16, 1916.

tion of tungsten incandescent lamps in America increased 33 per cent. over 1915; about 200,000,000 lamps were manufactured.

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URANIUM AND VANADIUM

By Robert M. Keeney

Uranium

The production of uranium in the form of ferro-uranium increased in 1916 due to commercial confirmation of its value in high-speed steel, after its first use for this purpose late in 1915. Several brands of uranium high-speed steel were placed upon the market.

Source.—Accurate figures are not available as to the quantity of uranium mined in 1916. As in previous years the chief producers were the radium manufacturers, including the National Radium Institute, the Standard Chemical Co., and the Schlesinger Radium Institute. Of these producers only one disposes of any quantity of uranium in manufactured form, the Standard Chemical Co., which converts its uranium oxide to ferro-uranium. The Bureau of Mines developed a process for manufacture of ferro-uranium from uranium oxide in the electric furnace, and obtained patents on the conversion of sodium uranate to uranium oxide.

In Colorado considerable assessment work and development work was done on carnotite claims. In Utah there was no production of uranium ores.

Prospecting[1] was recently done on the pitchblende and uranium ochre deposits which have been known for many years to occur at the Singa mica mines in the Gaya district of India. Here the pitchblende occurs in a pegmatite dike. On the surface there is yellow uranium ochre in small amounts, but deeper pitchblende is found.

Market.—In January 1917, 70 per cent. sodium uranate was quoted at $2.50 per lb. of U_3O_8 contained, and 96 per cent. uranium oxide at $3.60 per lb. of U_3O_8 contained. In large quantity 85 per cent. uranium oxide was offered at $2.50 per lb. of U_3O_8 during the latter part of 1916. Standard grade of ferro-uranium containing 35 to 50 per cent. uranium and 1.5 to 3 per cent. carbon sold at $7.00 per lb. of contained uranium.

Uses.—Practically the entire use of ferro-uranium was in high-speed steel manufacture. Three patents[2] were issued to the Standard Chemical Co. on uranium steel of about the same composition as indicated to be the best proportions by their experiments and those of one of the steel

[1] *Comm. Rept.*, May 1, 1916, p. 408.
[2] U. S. Patents, 1,201,625; 1,201,626; 1,201,627; Jan. 2, 1917.

manufacturers made a little previous. The first patent refers to the use of uranium as the sole toughening agent, and specifies a content of from 0.05 to 5 per cent. of uranium in the steel. In the second patent it is stated that by incorporating 3 per cent. of uranium into tungsten steel containing as low as 8 per cent. tungsten, a high-speed steel is produced which has all the qualites of tungsten steel containing 18 per cent. tungsten. The third patent refers to the analogous addition of 0.4 to 3 per cent. of uranium to molybdenum steel containing from 3 to 10 per cent. molybdenum. It is probable that most of the uranium steel being manufactured conforms to the second patent, a steel with 3 per cent. uranium, 8 per cent. tungsten and the usual amounts of chromium and vanadium. Steel containing only 1 per cent. uranium shows about as good cutting qualitites as the steel containing 3 per cent. uranium. Steel containing much over 3 per cent. uranium shows a tendency to crack on forging.

Tests on the cutting qualities of uranium high-speed steel made by the Standard Chemical Co. gave the following results.[1] One tool fed at the rate of $\frac{1}{16}$ in. per revolution at a cutting speed of 74 ft. per min., with a cut $\frac{5}{8}$ in. in depth, went a distance of 12 in. before re-grinding was necessary. A tool turning a locomotive crank pin, operating at a speed of 103 ft. per min., with a feed of $\frac{3}{32}$ in. and cut $\frac{5}{8}$ in. in depth, went 8 in. before it was re-ground. On a locomotive axle, a tool with a $\frac{1}{16}$-in. feed and a cutting speed of 75 ft. per min. went a distance of 14 in. on the first and 3 in. on the second lap before it was re-ground. The depth of cut was $\frac{1}{4}$ in. On a 12-in. shaft, 22 ft. long, a tool fed at the rate of $\frac{1}{16}$ in. to $\frac{1}{10}$ in., at a speed of 38 ft. per min., with a depth of cut $\frac{15}{16}$ in., went 127 in. It took 3 hr. to conduct this test. After the tool had gone 105 in., the cutting speed was increased to 65 ft. per min. From these tests uranium steel compares very favorably with other high-speed steels.

The future of uranium as a steel-making metal depends largely upon the ore supply. At present it does not appear that uranium will ever be a great competitor of tungsten because of the limitations of the known deposits of uranium ore. In comparison with tungsten-ore deposits, the carnotite deposits of Colorado are small and can produce only a limited amount of uranium. Practically all the uranium entering steel manufacture now comes from Colorado.

Vanadium

There was a great increase in the demand for ferro-vanadium, both for domestic consumption and foreign shipment. Export shipments

[1] *Met. Chem. Eng.*, Aug. 1, 1916, p. 159.

doubled, being for 1916 at the rate of 700,000 lb. of contained vanadium yearly, as against 300,000 lb. in 1915. During 1916, 2,013,027 lb. of ferro-vanadium valued at $2,035,276 were exported. Taking the rate of the last 3 months of 1916, exports are now at the rate of 3,400,000 lb. of ferro-vanadium yearly, or 1,100,000 lb. of contained vanadium. The price remained about the same as in 1915, $2.25 to $3.00 per lb. of vanadium, but early in 1917 the price advanced to $3.25 per lb. for small shipments.

The production of vanadium steel is given in "American Vanadium Facts" as 800,000 tons in 1916, compared with 450,000 in 1915 and 90,000 in 1913.

Sources.—The chief source of vanadium continued to be the Minasragra mine of the American Vanadium Co. in Peru, from which in 1915 2526 tons of ore was exported to the United States with a much larger output possible. The Primos Chemical Co. operated its plant in Colorado at capacity on roscoelite ore. The Standard Chemical Co. produced a considerable quantity of ferro-vanadium from Colorado carnotite ore, but the total output from Colorado was small in comparison with the Peru production. There was some mining activity in connection with the vanadinite ores of Arizona and New Mexico.

An occurrence of mattranite, copper-lead-vanadate, was reported[1] in the Grootfontein district at Rietfontein, South Africa, where it is found with cerrusite. From this place several tons of ore containing 7 per cent. V_2O_5 have been produced, all coming from the surface.

Metallurgy.—An extensive research was conducted by Siegfried Fischer[2] on the electrolysis of aqueous solutions of vanadium salts, the object being to determine whether metallic vanadium could be obtained from aqueous solutions of its salts. He concludes that the element vanadium is not likely to be obtained as a cathode deposit from aqueous salt solutions, due to the high heats of formations of the salts, and to the great tendency vanadium has to form vanadates.

The treatment of the lead vanadate ore at Cutter, N. M., is described by P. L. Grider.[3] The ore occurs in a gangue, mostly calcareous, and usually containing quartz and barite. Due to the small difference in specific gravities it is difficult to separate the vanadium minerals from the barite by concentration. The ore was crushed in a jaw crusher, rolls and an Elspass mill, and concentrated on Wilfley tables, vanners and slime tables. With this treatment the best saving on 1 per cent. V_2O_5 ore was 69 per cent., giving a mill product of Wilfley concentrate, 8 to 9 per cent. V_2O_5, secondary concentrate 4.5 to 5 per cent. V_2O_5,

[1] *So. Af.. Min. Jour.*, June 24, 1916.
[2] *Trans. Am. Electrochem. Soc.*, **30**, 175 (1916).
[3] *Min. Sci. Press*, Sept. 9, 1916.

slime 0.7 to 1.85 per cent. V_2O_5. When rolls were substituted for the Elspass mill, due to formation of less slime, and re-grinding in a Hardinge mill, a recovery of 80 to 86 per cent. of the vanadium was made.

The higher-grade ore and concentrate was treated by smelting with soda ash and coal, giving metallic lead and sodium vanadate slag practically free from copper, arsenic and phosphorus. With an ore containing 36 per cent. V_2O_5 and 23.54 per cent. lead, the recovery of lead as bullion was 90.5 per cent., and the extraction of vanadium in the form of slag was 98.5 per cent. The slag was very low-grade, however, containing 5.22 per cent. V_2O_5, too low-grade for direct production of ferro-vanadium.

The slag was crushed, mixed with sulphuric acid, baked to a dry cake, crushed, and boiled with water for several hours. The vanadium solutions were filtered and evaporated, giving vanadium sulphate. The sulphur was driven off by roasting, followed by granulation of the semi-molten mass in water. This granulated vanadium residue was used for production of ferro-vanadium by the thermit process.

In discussing the use of ferro-alloys, J. E. Johnson, Jr.[1], states that the principal service of vanadium is not in remaining with the steel itself, but in going out of it with the oxygen, nitrogen, etc., which it removes, according to its best-informed advocates. It seems almost certain, he states, that it will be found objectionable in good irons containing oxygen, as it has already been found to be without benefit for ordinary castings not containing oxygen. Great claims have been recently made for iron containing traces of vanadium, but the photomicrographs used to illustrate the claims did not display a particularly good structure, and the results of physical tests given were far below the results obtainable with iron containing oxygen.

[1] *Met. Chem. Eng.*, Dec. 1, 1916, p. 643.

ZINC

By Jesse A. Zook

A Foreword.—Conditions have changed with remarkable rapidity since this review was begun. In the middle of May, 1917, the submarine blockade so upset shipping facilities that ocean freight was confined to the shipping of food, war munitions, transports and some spelter. Ore shipments have ceased in all directions across the water. This will seriously curtail production of spelter in Great Britain, and means that, with the United States joined with the Allies against Germany, North America will be called upon to supply all the ore and all the spelter for the Western front of the war, a condition that will maintain until the submarine blockade is broken.

Producers of the Joplin district established a metal board and find that a base of $80 per ton 60 per cent. Zn will not afford operating expense, with amortization of overhead charges.

Recent action by United States Government authority is embodied in the following from the *Engineering and Mining Journal* of May 12, 1917:

The Zinc Committee of the Advisory Commission of the Council of National Defense, appointed by B. M. Baruch, in charge of raw materials of the Advisory Commission of the Council of National Defense is as follows:

Chairman, Edgar Palmer, president, New Jersey Zinc Co.

Charles W. Baker, president, American Zinc, Lead and Smelting Co.

Sidney J. Jennings, vice-president, United States Smelting, Refining and Mining Co.

Thomas F. Noon, president, Illinois Zinc Co.

N. Bruce MacKelvie, president, Butte & Superior Mining Co.

Charles T. Orr, president, Bertha A. Mining Co.

C. F. Kelley, vice-president, Anaconda Copper Mining Co.

Secretary, A. P. Cobb, vice-president, New Jersey Zinc Co.

The purpose of this committee is to insure the Government of its supply of zinc during the war and to secure the coöperation of the zinc producers of the country in taking care of whatever needs may arise.

The following prices for slab zinc have been fixed with Government approval:

Grade A—11½ cts. per lb.

Grade B—11 cts. per lb.

Grade C—9 cts. per lb.

The price of Grade C is protected against decline.

These prices are in carload lots with freight allowed to New York delivery rate points.

During the war Grade A metal has sold as high as 42 cts. per lb., and the market price at the time of making these prices was 18 cts. per lb. Grade C metal has sold as high as 27½ cts. per lb., and the market price at the time of making these prices was 10 cts. per lb.

Letters have been sent to zinc producers throughout the country asking the amounts they are willing to supply to the Government.

Grade A is what is commonly known as "high-grade," B is "intermediate" and C is "prime western."

The world war has brought spelter into a prominence not believed possible by the veriest dreamer. Through this prominence of spelter arose a demand for zinc ore that caused development of ore areas little known and previously undeveloped, completing a belt practically around the world. During 1916 ores were brought into the United States from Australia, China and Japan, for smelting. During the year the oriental countries made rapid strides in the development of zinc ores. Domestic production of zinc ores increased under strenuous demand until ore importations, except from Canada and Mexico, were unnecessary at the close of the year. By the close of 1916 the Joplin district reached a production of ore 90 per cent. greater than the normal production prior to the world war. The abundance of obtainable zinc ore made it possible for smeltermen to hold the price down after midyear to a bare working margin for the older mines of the Joplin district, while during the larger part of the year smelting profits were so enticing that new smelters sprang up like magic in the gas sections of Oklahoma, and all old, unused-for-years coal smelters were placed in commission, for use a part of the year. The Oklahoma gain of 67 per cent. in smelting capacity in 1916 over 1915 was closely followed by Pennsylvania with an increased smelting capacity of nearly 60 per cent. Mr. C. E. Siebenthal of the United States Geological Survey has compiled interesting data on the increased smelting capacity, in the following tables:

ACTIVE ZINC SMELTERS IN THE UNITED STATES, IN 1915 AND 1916

[Includes plants working on ore alone, on ore and drosses, and on drosses alone]

Operating Company. (A—acid plant; not necessarily at the smelter.)	Location.	Retorts at Close of 1915.	Retorts at Close of 1916.	Additional retorts contemplated or under construction.
Arkansas.				
Arkansas Zinc & Smelting Corporation	Van Buren	....	3,200	....
Athletic Mining & Smelting Co	Fort Smith	....	....	2,400
Fort Smith Spelter Co	do	....	2,560	....
Colorado.				
United States Zinc Co	Pueblo	....	5,760	2,400
Total		2,208	1,984	264
Illinois.				
American Zinc Co. of Illinois (A)	Hillsboro	4,000	4,864	....
Collinsville Zinc Smelter	Collinsville	1,792	2,304	....
Granby Mining & Smelting Co (A)	East St. Louis	3,220	4,820	800
Hegeler Zinc Co (A)	Danville	3,600	5,400	....
Illinois Zinc Co (A)	Peru	4,640	4,640	800
Matthiesson & Hegeler Zinc Co (A)	La Salle	6,168	6,168	....
Missouri Zinc Co	Beckemeyer	352	352	....
Mineral Point Zinc Co (A)	Depue	9,068	9,068	....
National Zinc Co (A)	Springfield	3,200	4,480	....
Robert Lanyon Zinc & Acid Co (A)	Hillsboro	1,840	3,200	....
Sandoval Zinc Co	Sandoval	672	672	672
Total		38,552	45,968	2,272
Kansas.				
American Spelter Co	Pittsburg	896	992	....
American Zinc, Lead & Smelting Co	Caney	6,080	6,080	....
Do	Dearing	4,480	4,480	....
Chanute Spelter Co	Chanute	1,280	1,280	....
Cherokee Smelting Co	Bruce	896	896	....
Edgar Zinc Co	Cherryvale	4,800	4,800	240
Granby Mining & Smelting Co	Neodesha	3,760	3,760	....
Iola Zinc Co	Concreto	660	1,320	....
Joplin Ore & Spelter Corporation	Pittsburg	1,444	1,792	....
Lanyon Smelting Co	do	448	448	....
Owen Zinc Co	Caney	1,280	1,920	....
Pittsburg Zinc Co	Pittsburg	910	910	....
Prime Western Spelter Co (A)	Gas	4,868	4,868	....
United States Smelting Co	Altoona	3,960	4,600	....
Do	Iola	3,440	3,440	....
Do	La Harpe	1,924	1,926	....
Weir Smelting Co	Weir	....	288	....
Total		41,126	43,800	240
Missouri.				
Edgar Zinc Co	St. Louis	2,000	2,000	....
Missouri Zinc Smelting Co	Rich Hill	....	448	....
Nevada Smelting Co	Nevada	672	672	....
Total		2,672	3,120	....
Oklahoma.				
Bartlesville Zinc Co	Bartlesville	5,184	6,336	....
Do	Blackwell	....	9,600	....
Do	Collinsville	10,752	13,440	....
Bartlesville Zinc Co. (Lanyon-Starr plant)	Bartlesville	3,456	3,456	....
Eagle-Picher Lead Co	Henryetta	....	4,000	....
Henryetta Spelter Co	do	....	3,000	....
Kusa Spelter Co	Kusa	3,720	7,720	....
National Zinc Co	Bartlesville	4,970	4,970	....
Oklahoma Spelter Co	Kusa	....	1,600	....
Quinton Spelter Co	Quinton	....	1,344	1,344
Tulsa Fuel & Manufacturing Co	Collinsville	6,232	6,232	....
United States Smelting Co	Checotah	....	5,120	....
United States Zinc Co	Sand Springs	5,680	8,000	200
Western Spelter Co	Henryetta	....	2,400	....
Total		39,994	77,218	1,544
Pennsylvania.				
American Steel & Wire Co (A)	Donora	3,648	9,120	....
American Zinc & Chemical Co (A)	Langeloth	3,648	7,296	....
New Jersey Zinc Co. (of Pennsylvania)	Palmerton	6,720	7,200	....
Total		14,016	23,616	....

ACTIVE ZINC SMELTERS IN THE UNITED STATES IN 1915 AND 1916.—(*Continued*)
[Includes plants working on ore alone, on ore and drosses, and on drosses alone].

Operating Company. (A—acid plant; not necessarily at the smelter.)	Location.	Retorts at Close of 1915.	Retorts at Close of 1916.	Additional retorts contemplated or under construction.
West Virginia.				
Clarksburg Zinc Co.	Clarksburg	3,648	3,648	....
Grasselli Chemical Co. (A)	do	5,760	5,760	....
Do.	Meadowbrook	8,592	8,544	....
United Zinc Smelting Corporation (A)	Moundsville	....	....	6,912
Total		18,000	17,952	6,912
Grand Total		156,568	219,418	13,632
PLANTS WITH SPECIAL RETORTS.[a]				
Eastern Zinc Refining Co.	Brooklyn, N. Y.	....	8	16
John Finn Metal Works	San Francisco, Cal	....	2	1
Michael Hayman & Co.	Buffalo, N. Y.	12	12	....
M. M. S. Metal Co.	Trenton, N. J.	....	21	....
Trenton Smelting & Refining Co.	do	96	96	....
William Cramp & Sons Ship & Engine Building Co.	Philadelphia, Pa.	32	32	....
Total Large Retorts		140	171	17

a Large graphite retorts yielding 600–800 pounds of spelter per charge.

ELECTROLYTIC ZINC PLANTS IN THE UNITED STATES

Company.	Location of Plant.	Daily Spelter Capacity.	Remarks.
American Smelting & Refining Co.	Murray, Utah	Experimental	Operated in 1916.
Anaconda Copper Mining Co.	Anaconda, Mont.	25 tons	Operated in 1915–16; now idle.
Anaconda Copper Mining Co.	Great Falls, Mont.	200 tons	Under construction; 100 tons in operation at end of 1916.
Basin Salvage Co.	Basin, Mont.	Experimental	Under construction.
Bully Hill Copper Co.	Bully Hill, Cal.	Experimental	Operated in 1915–16.
Electrolytic Zinc Co.	Baltimore, Md.	10 tons	Operated in 1916.
Judge Mining & Smelting Co.	Park City, Utah.	15 tons	Completed March, 1917.
Mammoth Copper Mining Co.	Kennett, Cal.	25 tons	Will be completed by May, 1917.
Reed Zinc Co.	Palo Alto, Cal.	Experimental	Operated in 1914–15; idle in 1916.
River Smelting & Refining Co.	Keokuk, Iowa	10 tons	Operated in 1916.
Western Metals Co.	Georgetown, Colo.	Ore capacity, 100 tons.	Malm process; under construction.

Mr. Siebenthal's comments and deductions in reference to his foregoing data are given herewith:

The zinc-smelting capacity of the United States continued to expand during the later half of 1916, the total number of retorts at the beginning of the year being 156,568, at the midyear 196,640, and at the end of the year 219,418, when, also, 13,632 retorts were under construction or contemplated. The 219,418 retorts reported at the end of the year, at an annual yield under average conditions of 4 tons of prime western spelter each, would have a capacity of over 875,000 tons as compared with the capacity of 825,000 tons estimated in April, 1916, for the end of the year. This statement means that, given the ore, the smelters could produce 875,000 tons of prime western smelter in 1917, not that they will do so. In view of the account in the *Engineering and Mining Journal* of Mar. 31, 1917, of the 10 years' run of a furnace at Cherryvale, Kan., which had a yearly average of 4.86 tons per retort, the Geological Survey's estimate of 4 tons per retort under average conditions will probably not be considered excessive.

In 1916, as in 1915, a large number of retorts were engaged in refining prime western spelter by redistillation and were therefore not available to treat ore. A considerable number of retorts were idle during the year, over 11,500 being idle Dec. 31. Thirteen zinc smelters were started and brought to an operating stage during the year and two more were begun. A feature of this smelter building has been the rapidity and secrecy with which gas smelters have been built in the Southwest. So far as known to the writer, the Western Spelter Co.'s plant at Henryetta, Okla., owned by the Nicholson interests, reached an operating stage before it was mentioned in the technical press. It is reported that the Grasselli Chemical Co. is building a zinc-smelting and acid plant at Terre Haute, Ind., but the United States Geological Survey has not yet been able to learn the details of the plant. In October the Kusa and La Harpe plants at Kusa, Okla., were consolidated as the Kusa Spelter Co.

The capacity of the electrolytic zinc plants in the United States at the end of 1916 hardly came up to the Geological Survey's estimate of 60,000 tons, owing to the failure to complete some plants. Electrolytic plants were in reality producing at the rate of 40,000 tons annually, but with the completion of plants now under construction the capacity will be about 85,000 tons. The production of electrolytic spelter in 1916 was 12,916 tons, of which 1800 tons was refined from prime western spelter, 887 tons was refined from scrap and drosses, and 10,229 tons was made from ore.

Production and Consumption of Spelter

The accompanying compilations of C. E. Siebenthal, published by the U. S. Geological Survey, give the production and consumption of primary spelter in the United States, also exports and imports of zinc ores, and products containing zinc.

PRODUCTION OF SPELTER IN THE UNITED STATES IN 1916
(In tons of 2000 pounds.)

	1915	1916	Increase in 1916 Quantity.	Per Cent.
Production of primary spelter[a] in United States	489,519	667,456	177,937	37
Consumption of primary spelter in United States	364,382	458,428	94,046	26
Value of primary spelter produced in United States	b$121,401,000	b$178,878,000	$57,477,000	47

PRODUCTION OF PRIMARY SPELTER IN THE UNITED STATES
(Apportioned according to source of ore.)

United States:	1911	1912	1913	1914	1915	1916
Total domestic	271,621	323,907	337,252	343,418	458,135	563,451
Foreign:						
Canada	1,598	4,199	1,424	4,538	5,103	24,376
Mexico	13,307	10,700	6,205	5,093	13,943	20,694
Europe	....	....	1,175	....	1,073	12,379
Africa	....	....	....	....	....	2,016
Asia	....	....	620	....	1,030	1,905
Australia	....	....	....	....	10,235	41,958
Other countries	....	....	....	....	....	677
Total foreign	14,905	14,899	9,424	9,631	31,384	104,005
Grand total	286,526	338,806	346,676	353,049	489,519	667,456

APPORTIONED ACCORDING TO LOCALITY IN WHICH SMELTED

Illinois	83,130	88,397	106,654	127,946	159,958	181,433
Kansas	98,413	101,104	74,106	44,510	101,423	141,286
Oklahoma	46,315	76,925	83,214	91,367	109,208	168,206
Other States	58,668	72,380	82,702	89,226	118,930	176,531
Total	286,526	338,806	346,676	353,049	489,519	667,456

PRODUCTION OF SECONDARY ZINC IN THE UNITED STATES

Secondary spelter, redistilled	14,043	26,064	25,991	20,545	29,764	29,663
Secondary spelter, remelted	26,470	26,187	24,014	22,424	23,136	(*c*)
Recovered zinc in alloys, excluding old brass remelted	3,223	3,912	3,743	3,914	5,300	(*c*)

CONSUMPTION OF PRIMARY SPELTER IN THE UNITED STATES

Supply:						
Stock, Jan. 1:						
In bonded warehouses	31	32	48	....	111	32
At smelters	23,201	9,049	4,474	40,659	19,984	14,221
Production:						
From domestic ore	271,621	323,907	337,252	343,418	458,135	563,451
From foreign ore	14,905	14,899	9,424	9,631	31,384	104,005
Imports	609	11,115	6,100	880	904	684
Total available	310,367	359,002	357,298	394,588	510,518	682,393
Withdrawn:						
Exports, foreign, from warehouse	11,276	6,286	6,027	5,580	12,776	43,230
Exports, foreign, under drawback	3,079	1,219	7,459	4,981	255	....
Exports, domestic	6,872	6,634	7,783	64,807	118,603	163,137
Stock, Dec. 31:						
In bonded warehouses	32	48	....	111	32	90
At smelters	9,049	4,474	40,659	19,984	14,221	17,508
Total withdrawn	30,308	18,661	61,928	95,463	145,887	223,965
Apparent consumption	280,059	340,341	295,370	299,125	365,438	458,428

EXPORTS OF DOMESTIC ZINC ORE AND DROSS

Zinc ore	18,281	23,349	17,713	11,110	832	78
Zinc dross	4,246	205	28	2,526	4,167	48

IMPORTS OF ZINC ORE AND ZINC DUST

Zinc ore	39,116	43,940	31,416	31,962	158,852	385,964
Zinc content	15,933	17,567	13,497	12,132	57,669	148,147
Zinc dust	....	....	2,191	2,302	856	934

a Primary spelter is made directly from ore; but secondary spelter is recovered from such sources as drosses, skimmings, and old metals.

b Value calculated from average selling price.

c Subject to revision.

NOTE.—Imports and exports of spelter are given under the heading "Consumption." The imports of spelter in 1909–1916 are as given in the December Summary of the Bureau of Foreign and Domestic Commerce, except that for 1909–1912, inclusive; the quantities given therein have been diminished by the quantity of zinc dust imported since Aug. 6, 1909, for the reason that the imports of spelter and zinc dust for that period were not separated in the summary. The imports of spelter do not include sheet zinc, but include a few hundred tons of old zinc, fit only for remanufacturing. The stock in bonded warehouses does not include zinc ore in bond or the spelter made therefrom, such spelter being included in stock at smelters.

EXPORTS

ZINC EXPORTED FROM THE UNITED STATES, BY 6-MONTH PERIODS, 1915–1916, BY CLASSES, IN POUNDS

Material.	1915.				1916.			
	January-June.		July-December.		January-June.		July-December.	
	Quantity (pounds).	Value.	Quantity (pounds).	Value.	Quantity (pounds).	Value.	Quantity (pounds).	Value.
Domestic.								
Zinc ore	1,355,200	$24,791	309,120	$10,485	67,200	$1,792	89,600	$2,200
Spelter and sheets	128,735,815	11,627,295	108,470,113	17,910,385	116,014,559	20,575,060	210,260,527	30,737,930
Zinc dross	5,863,250	345,387	2,470,263	161,569	56,025	3,080	40,550	7,721
Zinc manufactures	....	1,047,975	....	1,125,114	....	304,452	....	267,834
Brass, old, for remanufacturing	8,662,272	912,896	2,594,400	346,742	2,568,093	527,884	4,388,267	777,191
Brass, bars, plates, and sheets	36,251,304	5,683,217	30,020,806	6,752,689	103,085,355	28,917,034	141,446,349	43,766,592
Brass, articles made from	....	10,924,990	....	30,192,781	....	98,110,795	....	143,557,286
Cartridges	....	13,043,498	....	11,771,181	....	24,718,907	....	30,384,997
Foreign.								
Zinc ore, contents	....	....	....	....	....	....	....	....
Zinc, blocks, pigs, and old	11,408,033	336,399	14,142,981	2,110,571	40,395,441	4,154,327	46,064,054	3,926,115
Zinc dust	227,408	22,680	204,407	32,707	157,671	29,357	232,907	28,338
Zinc manufactures	....	54,124	....	64,980	....	1,072	....	....
Brass, old, for remanufacturing	....	....	....	....	....	....	....	....
Zinc used in articles exported with benefit of drawback	510,678	[a]65,000	....	....	....	....	....	....
	....	44,088,252	....	70,479,204	....	177,343,769	....	253,456,204

a Represents the value of the metal used in making the articles exported with benefit of drawback.

SPELTER AND SHEET ZINC EXPORTED FROM THE UNITED STATES, BY 6-MONTH PERIODS, 1915–1916, BY DESTINATION, IN SHORT TONS

Destination.	1915.				1916.			
	January–June.		July–December.		January–June.		July-December.	
	Domestic.	Foreign.	Domestic.	Foreign.	Domestic.	Foreign.	Domestic.	Foreign.
Canada	2,918	382	6,561	203	4,634	638	5,584	70
Breat Britain	31,100	3,477	23,452	1,645	19,188	6,481	41,341	12,336
Netherlands	....	....	12	....	6	....	3	....
France	15,849	1,396	9,406	4,668	18,804	11,178	33,006	8,287
Italy	2,717	448	6,051	504	5,807	1,901	8,274	2,032
Germany	....	....	....	....	....	....	....	....
Russia	6,671	....	5,420	....	3,219	....	8,567	124
Japan	187	....	470	....	610	....	272	....
Other countries	4,926	1	3,063	51	5,739	....	8,083	153
	64,368	5,704	54,235	7,071	58,007	20,198	105,130	23,032

SPELTER AND SHEET ZINC EXPORTED FROM THE UNITED STATES, BY MONTHS, 1915–1916, IN SHORT TONS

Month.	1915.			1916.		
	Domestic.	Foreign.	Foreign Zinc Used in Articles Exported with Benefit of Drawback.	Domestic.	Foreign.	Foreign Zinc Used in Articles Exported with Benefit of Drawback.
January	15,299	84		10,483	3,531	
February	15,002	2,016		10,328	3,919	
March	8,120	1,136		8,171	575	
April	8,842	77	255	9,133	1,902	....
May	7,635	1,104		8,583	4,811	
June	9,470	1,286		11,309	5,459	
July	6,492	1,876		12,709	4,508	
August	7,274	421		18,662	4,232	
September	8,653	1,513		19,125	965	
October	12,093	608	....	19,994	6,110	....
November	10,019	2,343		18,988	4,260	
December	9,704	310		15,652	2,958	
	118,603	12,776	255	163,137	43,230	

IMPORTS

ZINC ORE IMPORTED INTO THE UNITED STATES, 1915–1916, IN SHORT TONS

Source.	1915.			1916.		
	Ore.	Zinc content.	Value.	Ore.	Zinc content.	Value.
Canada	11,992	4,710	$177,868	21,908	8,790	$567,259
Mexico	57,699	17,804	2,130,014	161,271	51,028	5,779,564
France	....	....	....	3,884	1,422	56,542
Spain	....	....	....	55,965	23,081	1,550,334
Italy	5,312	2,125	153,388	12,550	5,783	394,782
French Africa	....	....	....	4,480	1,857	129,153
French East Indies	....	....	....	1,653	746	55,407
China and Hongkong	5,880	2,738	119,913	9,641	4,568	344,192
Japan	1,369	499	77,899	....	....	....
Australia	76,410	29,723	1,843,801	110,600	49,657	3,117,304
New Zealand	....	....	....	3,262	944	105,880
Other countries	190	69	7,663	750	271	20,968
	158,852	57,669	4,510,546	385,964	148,147	12,121,385

Prices and Value.—Concluding, Mr. Siebenthal draws the important comparison of spelter prices of 1916 with 1915, as follows:

In 1915 the average price quoted for prime western spelter for immediate delivery at St. Louis was 14.2 cts. a pound. Large quantities of spelter were sold for future delivery at considerable reductions in price. Returns from each producer showed an average price received of 12.4 cts. In 1916 the average price quoted for spelter for immediate delivery at St. Louis was 13.6 cts. a pound, and the average price received for spelter of all qualities—prime western, brass special, and high-grade—was 13.4 cts. The smaller difference between the price quoted and the price received in 1916 is probably due to increase in domestic consumption, to decrease in sales for future delivery, and to the production of a larger proportion of high-grade spelter.

Production

A quarterly report of the spelter production marks the steady increase throughout the year.

SPELTER PRODUCTION, 1913–1916, BY QUARTERS[1]

(In tons of 2000 lb.)

Reports of ore smelters only

District.	I.	II.	III.	IV.
1913.				
Illinois	27,924	28,523	26,118	28,986
Kansas-Missouri	22,006	23,820	19,204	20,127
Oklahoma	21,430	21,840	18,502	21,458
Others (a)	20,722	20,153	19,238	18,211
Totals	92,082	94,336	83,062	88,782
1914.				
Illinois	31,005	32,482	32,512	34,588
Kansas-Missouri	13,939	14,659	13,193	11,633
Oklahoma	22,563	22,960	22,945	23,999
Others (a)	22,717	22,715	24,106	24,296
Totals	90,224	92,816	92,756	94,516
1915.				
Illinois	35,786	39,511	41,791	44,577
Kansas-Missouri	14,090	24,554	32,152	40,256
Oklahoma	24,713	26,984	28,613	31,095
Others (a)	26,255	30,575	31,360	34,830
Totals	100,844	121,624	133,916	150,758
1916.				
Illinois	45,072	45,495	42,077	48,609
Arkansas	......	......	2,977	4,645
Kansas-Missouri	37,830	41,585	39,174	32,857
Oklahoma	34,994	38,786	41,387	49,919
Others (a)	37,853	39,902	41,586	47,552
Totals	155,749	165,768	167,201	183,582

(a) With the exception of one plant in Colorado these are all Eastern works. In the fourth quarter of 1915 and in 1916 is included Anaconda and other electrolytic production.

To the Oklahoma gas smelters belongs the greatest increase of the year, the electrolytic and Eastern production, including Pennsylvania, coming second. While Kansas had more retorts in 1916 than in 1915, a reduction in the production of spelter tells of the closing of the coal smelters after midyear. The third quarter marked a decline in the Illinois group, more than recouped with the operation of new retorts the last quarter. Arkansas came in line in the third quarter with new smelters in operation at Fort Smith and Van Buren, almost doubling in production the last quarter, although the increase in number of retorts was negligible.

Zinc Mining in the United States

Arizona.—According to the U. S. Geological Survey report the production of zinc from the mines increased from 18,220,863 lb., valued at $2,259,387, in 1915 to about 20,980,000 lb., valued at $2,874,260, in 1916, an increase of nearly 27 per cent. in value. The greater part of the zinc ore and concentrates was shipped from the Golconda and Tennessee

[1] *Eng. Min. Jour.*

properties, in Mohave County. There were, however, two new and important shippers of zinc ore—the Magma Copper Co. in Pinal County, which opened up zinc ore and constructed a concentrator late in the year, and the Duquesne property, in Santa Cruz County. Shipments were also made from the Kingman Zinc Co. near Kingman, the San Xavier mine, in Pima County, and the Gemmill-Randolph tailings at Crownking. Possibly 28,000 tons of crude zinc ore and concentrates were shipped from the State during the year.

Arkansas.[1]—Zinc and lead ore shipments from Northern Arkansas are aggregating 80 to 100 carloads per month. About 85 per cent. of this is zinc carbonate, 5 per cent. sphalerite and 5 per cent. lead, chiefly galena. The chief zinc- and lead-producing counties are Boone, Marion, Baxter and Searcy. Shipping points are on the White River division of the Iron Mountain R. R. for the eastern portion and the North Arkansas R. R. for the western portion. Rush, Maumee and other heavy producing camps are isolated from railroads, the cost of long hauls over mountainous roads being from $1.50 to $3 per ton of concentrate. A narrow-gage railroad is projected to Rush from Yelville, a distance of 14 miles. Wood fuel is used by some, but later installations are using oil fuel.

Arkansas ores occur chiefly in the Yelville formation of the Ordovician system, composed of magnesian dolomites as outcroppings, reaching a width of 500 ft. along the White river. The most valuable surface guide is the Key sandstone, marking the caprock overlying the dolomites in which the ore occurs. This sandstone has a resemblance to coarse brown sugar. Fracturing, jointing, faulting and slight brecciation characterize the ore areas. Blende produces a concentrate of 60 to 64 per cent. Zn, iron-free; carbonates a concentrate of 38 to 48 per cent. Zn.

Colorado.—Spelter registered a drop, the output being lower than in 1915 by 899,182 lb., in spite of the fact that the tonnage of zinc-bearing ore extracted in 1916 was materially greater. The loss in value of the spelter output was $966,493.

Idaho.[2]—The mine production of zinc increased from 70,153,234 lb. in 1915 to 86,505,219 lb.in 1916, or 23 per cent. The value of the output increased from $8,699,001 to about $12,000,000, or 38 per cent. The Consolidated Interstate Callahan was, as formerly, the most important producer, and shipped 68,000 tons of zinc ore and concentrate aside from lead product, and the Success contributed nearly the same amount of spelter. Other important producers were the Morning, Greenhill-Cleveland, and Frisco mines. Smaller shipments were made from the

[1] L. L. Wittich, contributed to *Eng. Min. Jour.*, Aug. 16, 1916, written just prior to his demise.
[2] U. S. Geol. Surv. report.

Terrible Edith, Paragon, Murray Hill, Highland Surprise, Constitution, Hercules, Colonial, Douglas, and Black Hawk, in Shoshone County, and the Minnie Moore, Nay Aug, Boston-Idaho, and North Star Triumph, in Blaine County, where a new mill was completed. The Ray Jefferson Co., joining the Interstate Callahan, completed the mill and made concentrates which were stored, awaiting the completion of the Beaver Creek branch of the O. W. R. & N. railroad.

Kansas, Oklahoma, Missouri (Joplin District).[1]—The year 1916 in the Joplin district was marked by metallurgical rather than mining advances. The increasing number of large mills change the outlook of the district from that of the uncertainty of the early-day mining camp to that of prosperous permanency. Supplanting the smaller mills are mills of 500-ton and 1000-ton capacity, and the number of these is increasing with new developments warranting sufficient ore reserves for several years' continuous operation. Reconcentration, too, is bringing low grades of blende from a non-salable to a marketable product.

Production responded slowly to increased mill capacity. A year ago it was noted that "a maximum production can not readily be increased." The high prices of 1915 produced an average of 5973 tons of zinc concentrates per week. The 1916 weekly production was 7491 tons.

A number of the new large mills erected during 1916 were situated at a disadvantage in the use of coal-burning power equipment, making its use inexpedient. The low gas pressure of last winter gave slight hope for gas-burning power equipment, consequently electric power was given preference. The hydro-electric company, with a dam below the junction of Spring River and Shoal Creek, on the edge of Kansas, and one in Taney County, Missouri, on White River, added an auxiliary steam plant of three turbine units near the Kansas dam site. Mine owners felt safe in adopting electric-power equipment. But an excessively dry summer so lowered the water in all streams that the steam plant became so overburdened that all three units were alternately crippled, and at the end of November dependence was centered upon one patched-up steam turbine. Low pressure prevented the use of gas, while the high price and scarcity of coal made its adoption impractical. Thus the year ends with a forced restriction to approximately 8000 tons production, when it could reach from 11,000 to 12,000 tons weekly if full power could be realized. There is but slight promise of a satisfactory adjustment of the power situation for a fortnight or two ahead. Mills dependent upon electric power are permitted only one-third operating capacity. An additional auxiliary steam plant is in course of construction, to be completed early in February.

[1] *Eng. Min Jour.*

TABLE II.—JOPLIN DISTRICT ORE SHIPMENTS, IN POUNDS, 1916

Missouri.	Blende.	Calamine.	Lead.	Values.
Jasper County	505,141,750	4,234,940	77,443,640	$26,351,210
Newton County	35,449,590	33,237,420	2,011,950	2,572,020
Lawrence County	6,742,830	9,490,770	314,940	565,580
Dade County	....	3,867,610	....	100,980
Green County	....	1,363,550	....	37,270
Christian County	158,860	759,040	142,870	28,750
Howell County	....	1,034,690	....	17,500
Moniteau County	64,910	....	....	3,400
Totals	547,557,940	53,988,020	79,913,400	$29,679,710
Oklahoma.				
Ottawa County	102,087,540	218,670	30,693,490	5,350,260
Kansas.				
Cherokee County	50,614,970	....	4,759,580	2,479,270
*Arkansas.	....	3,733,690	35,220	91,390
Total, 1916	700,260,450	57,940,380	115,401,690	$37,600,630
Total, 1915	597,699,980	51,357,650	93,225,380	28,397,030
Increase for 1916	102,560,470	6,582,730	22,176,310	9,203,600

* Ores sold in the Joplin district.

The past year was in a measure a reflex of 1915, with a retouch of the wide price range, though scarcely reaching the pyrotechnical display of 1915. The year opened with zinc blende at $112 per ton, advancing to $131.70 in mid-February, declining a month later to $112 and up to $127.35 in mid-April. Following came a steadily decreasing price level until in September the base price dropped as low as $45 the first week, then up to $55@65 the rest of the month. With October, prices started upward, closing November at $107.75 on a base range of $105@95. The second week of December brought a $5 lower price. Sellers, ever confident of a higher market, look forward to a repetition of last winter's high price level, especially on account of the enforced restriction of output. The price level of calamine was closely allied with that of blende, indicating like variations from a $90@80 base in January and April, declining to a

ORE PRICES IN JOPLIN DISTRICT
(15 Years)

Year.	Zinc Ore.	
	High.	Average.
1902	$42.00	$30.33
1903	42.00	33.72
1904	53.00	35.92
1905	60.00	44.88
1906	54.00	43.30
1907	53.50	43.68
1908	47.00	34.36
1909	55.00	41.08
1910	52.00	40.42
1911	51.00	39.90
1912	67.00	53.33
1913	59.00	42.26
1914	54.00	40.46
1915	138.90	79.30
1916	131.70	88.05

low base of $35@25 with the advent of September, then turning upward. Lead prices opened the year at $77, advancing to $104 in April, down to $68 at the end of August, when an upward action began that carried the price back to $100 early in December.

The year's shipment of 379,100 tons of blende-calamine is an increase of 54,570 tons. The lead shipment of 57,700 is an increase of 9000 tons. The 1916 value is $37,600,630, an increase of $9,203,600 as shown in Table II.

Montana.—According to the U. S. Geological Survey report the zinc production increased 20 per cent.

The mine production of zinc increased from 187,146,895 lb. in 1915 to 229,259,075 lb. in 1916, an increase of over 42,000,000 lb. In value the output increased from $23,206,215 to $31,099,000, or 34 per cent. The Butte & Superior Mining Co. was, as formerly, the greatest producer of zinc concentrates, shipping about 15,000 tons monthly for the first half of the year, according to the printed reports. The Elm Orly property, which is next in importance, also increased its zinc output, and large shipments were also made from the Iron Mountain mine and from tailings concentrated at Basin. A considerable quantity of electrolytic zinc was made by the Anaconda Co. largely from ores mined at Butte. The construction of a large zinc electrolytic plant at Great Falls was progressing rapidly, and at the close of the year three units were complete. The plant is to have five units and will make an output of 6,000,000 lb. of zinc a month. A zinc concentration plant having a capacity of 2000 tons was also constructed. About 233,000 tons of zinc concentrate and ore were shipped to Eastern plants, aside from ore treated by the Anaconda Co.

The *Metal Bulletin* of February 13, 1917, says:

The Anaconda Co. states that they will market their high-grade spelter as "zinc" under the brand "Anaconda Electric." It is stated officially that they can produce this for less than 3 cts. per lb., say £14 a ton. The capacity of the plant is nearly 45,000 tons a year.

Nevada.[1]—The mine production of zinc was approximately 34,739,000 lb., an increase of over 10,000,000 lb. from that of 1915. There was a greater increase in the value, from $3,022,680 to $4,759,000 or 57 per cent. Over 90 per cent. of the output came from the Yellowpine district, in Clark County, very largely from the Yellowpine and Potosi mines. Other important shipments of zinc ore or concentrates came from the Amalgamated Pioche property, in Lincoln County, and the Polar Star property, operated by the Nevada Zinc Mining Co. in Spruce Mountain district, Elko County.

[1] U. S. Geol. Surv. report.

New Jersey.[1]—The great zinc mines of the New Jersey Zinc Co. were operated on an increased scale in 1916, an additional mill of 800 to 900 tons' capacity having been completed and placed in operation at Franklin Furnace. This mill treats the finer sizes previously shipped in the crude to the smelteries; it also re-treats magnetic-separator middlings from the old mill, after crushing them to pass 30-mesh. The company re-opened the old mine at Sterling Hill and built a 450-ton mill, modeled on much the same lines as the Franklin Furnace practice. New Jersey iron mines were active, especially in the latter part of the year, and some prospecting was undertaken.

New Mexico.—In its report the U. S. Geological Survey notes that increased shipments of zinc carbonate and sulphide ores and zinc sulphide were made in New Mexico in 1916. At Kelly, Socorro County, the principal producing mines were the Kelly, Graphic, and Juanita. The Ozark mill was operated continuously up to the time of the fire in August. The Kelly magnetic mill was operated from May throughout the year. At Hanover, zinc carbonate ores were shipped from the Hanover mines and others, and from June on, zinc sulphide concentrates were shipped from the Hanover magnetic separation mill. The Cleveland magnetic separation mill, at Pinos Altos, was operated steadily. A mill was erected in the revived Steeplerock district, Grant County, and some shipments were made. Zinc carbonate ores were shipped from the Magdalena, Hanover, Cook's Peak, Florida Mountains, Tres Hermanas, and Pinos Altos districts. Shipments of zinc ore and concentrates from New Mexico were 73,900 tons of 30.15 per cent. grade, as compared with 41,852 tons of 36 per cent. in 1915.

In its issue of Jan. 6, 1917 the *Engineering and Mining Journal* reports that in Socorro County the Mogollon district operated steadily and the Pacific mine was connected with the Socorro mill by a tramway. The Mogollon Mines Co. operated its mill, and the Oaks Co. continued the development of the Clifton-Eberle group and other properties. Near Steeplerock there were interesting developments, the Carlisle being the most important operation. In the Magdalena zinc-lead district the mill of the Ozark Smelting and Mining Co. was burned on Aug. 10, and the plant is being rebuilt. Zinc-carbonate ore was in good demand, but the sulphide flotation concentrate was more difficult to market. New ore was opened in the Graphic, and in the Kelly mine of the Empire Zinc Co. which operated a dry-process magnetic-separating mill. The old White Oaks gold property in Lincoln County was optioned to the Keith interests, of Boston, and was developed for both tungsten and gold. Batopilas Mining Co. had a New Mexican property under exploration, its operations in old Mexico being closed.

[1] *Eng. Min. Jour.*, Jan. 6, 1917.

New York.—Development occupied operations largely. The *Engineering and Mining Journal* of Jan. 6, 1917, said that the principal zinc mine in New York at Edwards, St. Lawrence Co., was sinking a 1000-ft. two-compartment shaft to reach territory explored by diamond drills; the mill was run at capacity on ore from No. 1 and No. 2 mines, extraction from the latter, or White mine, having been begun through connections with No. 1 slope. In Sullivan County one of the old zinc-lead deposits was re-opened and was being equipped with a milling plant.

Texas.—The United States Geological Survey reports that the Presidio silver mine of Texas has been in continuous operation during the first 6 months of 1916, and that mining has been carried on actively during that period in the Van Horn and Sierra Blanca districts, all in the trans-Pecos country. The net result was a small output of copper, lead, and zinc, but a production of silver for the 6 months of fully 340,000 oz.

Utah.[1]—Prices for zinc continued high during the early part of the year, and much ore and concentrate containing the metal was marketed, but the price broke in May and was low in June, when a general falling off of the production was noticeable until the markets became settled. Altogether there were produced about 29,000,000 lb. of metallic zinc by 39 producers, against 24,292,240 lb. by 34 producers in 1915. The increase in value was nearly $1,000,000. No new zinc districts were opened in 1916, and the largest deposits of the higher-grade ores were about depleted in several districts. Some spelter was recovered electrolytically at one experimental plant, and another was about to start at the end of the year, its operators expecting to run it permanently. All the smelting plants—Murray, Garfield, Midvale, and International—were operating at full capacity the entire year.

Washington.[2]—The mine output of zinc increased from 244,906 lb. in 1915 to 1,693,734 lb. in 1916, an increase of approximately 600 per cent. The value increased from $30,368 to over $234,000. In Pend Oreille County, the Lead Zinc Co., at Metaline, increased its output of zinc ore and concentrate, and it is now planned to increase further the capacity of the mill, which treated 100 tons a day. The Norman Mines Co., near Northport, also shipped considerable zinc carbonate. The mine, however, was closed at the end of October.

Wisconsin.[3]—The high records of production and price of zinc ore of the year 1915 were exceeded in 1916. The net tonnage of zinc ore shipped to smelters from the Wisconsin district in the first 11 months of the year 1916 was 118,586 tons, an increase of 25 per cent. The lead ore shipped was 4009 tons, an increase of 26 per cent., while the shipment

[1] U. S. Geol. Surv., report.
[2] U. S. Geol. Surv.
[3] J. E. Kennedy, *Eng. Min. Jour.*

of sulphur ore, 28,999 tons, increased 118 per cent. The shipment of zinc ore by camps is given in the accompanying table.

WISCONSIN ZINC OUTPUT IN POUNDS, 1916
(First 11 months)

	Net to Smelters.		Gross from Mines.	
	1915.	1916.	1915.	1916.
Highland	3,538,060*	7,356,000*	3,538,060*	7,662,000*
Linden	12,716,810	6,236,000	13,111,660	26,768,000
Mifflin	9,202,560	9,384,000	49,619,750	56,222,000
Mineral Point	52,091,480	54,026,000	972,780	1,456,000
Dodgeville	1,109,150	842,000	1,109,150	992,000
Montfort	....	3,174,000	....	3,672,000
Platteville	18,735,760	9,120,000	15,098,470	29,664.000
Cuba City	31,605,060	39,382,000	3,642,600	7,892,000
Benton	36,759,190	76,522,000	119,173,940	170,814,000
Hazel Green	11,157,960	2,624,000	40,289,060	37,280,000
Shullsburg	1,130,300	1,408,000	5,712,300	15,258,000
Potosi	651,420	1,668,000	651,420	1,668,000
Galena	10,946,000	25,324,000	43,816,440	31,464,000
Dubuque	....	106,000	....	106,000
Totals	189,643,750	237,172,000	296,735,630	390,918,000
Increase	....	47,528,250	....	94,182,370

* Includes low-grade carbonate sludge ore from Highland.

The year opened at $110 per ton base for premium ore. During the first 19 weeks, with one exception, the base price for premium ore was in excess of $100 per ton; it remained below the $100 mark during the next 28 weeks, the average premium base price for this period being $68.85 per ton. The low premium base for this period was $56. The high premium base for the first quarter was $125. In 1915 the premium base was $100 or over during 14 weeks. The high premium base of 1915 was $130 per ton. An accumulation of second-class roasted ore, assaying as low as 52 per cent. zinc and as high as 6.5 per cent. lime and 1 per cent. lead, resulted from mining extremely low-grade deposits and from forcing milling capacity. A large stock of this ore, which did not meet with ready sale, caused a wide variation in the base price calculated upon a basis of 60 per cent. zinc content and lowered the base-price level of the Platteville market as compared with the Joplin market.

From 50 to 75 prospect drilling machines were busy throughout the year. Of this development work, 75 per cent. was done in the Benton-New Diggings camp, where a number of big deposits were uncovered. Among the abandoned properties re-opened, the Blockhouse at Platteville, formerly known as the Cruson, made the most remarkable showing with an output of 60 to 70 tons of 40 per cent. zinc concentrates in two 10-hr. shifts; the first 6 months' sales totaled over $100,000.

A total of 82 mills and 14 roasters were in operation during the year, of which 22 concentrating mills were constructed during 1916, namely: The Lampe, Clark No. 2 (both at Highland), Wicks, Spring Hill (Linden), Yewdall, M. & A. (Mifflin), Bell, New Rose (Platteville), Standard Metals (Cuba City), Mulcahy, Little Giant (Shullsburg), Tiffany (Potosi), Monmouth (Hazel Green), Hird, Longhorn, C. A. T., Sally, Meloy, Grand View, Bull Moose No. 2 (Benton-New Diggings), and Birkbeck and Little Corporal (Galena). The Blockhouse, Blackstone, Graham and McMillan were started in 1915 and completed in 1916. At the close of the year the Vinegar Hill Zinc Co. was constructing the Jefferson at Hazel Green, and the Mineral Point Zinc Co. was assembling material for a plant on the Meloy land, at New Diggings, owned in fee by the company. Roasting capacity was further increased by the completion of the Skinner-type roaster of the Mineral Point Zinc Co. at Mineral Point, the Mathey-type roaster of the Galena Refining Co. at Galena, the construction of a Mathey plant by the Oliver Mining Co. at the Mulcahy mine, Shullsburg, and the enlargement of the Campbell plants at Cuba City and Linden by the Linden Zinc Co. Of the 68 producing mines, with full equipment, in active operation Dec. 1, 1916, 56 were using electric power, the north end of the district being served by the Mineral Point Service Co., of Mineral Point, and the southern part by the Interstate Light and Power Co. of Galena.

In spite of high wages labor was scarce throughout the year, and the shortage not only hampered development, but impaired the efficiency of the working force. Shovelers, at 7 to 9 cts. per can, made \$3 to \$5 per day; underground drill men received from \$3 guarantee to \$5 with premium; on straight wages trammers generally received \$3.50 per day, hoistermen \$3.50, grizzlymen \$2.75, crusher feeders \$2.50, millmen \$90 to \$150 per month.

The macadamizing of country roads and the increased use of auto trucks facilitated transportation. Income tax derived from mining companies stimulated the good-roads movement; the Township of Benton alone assessed \$68,000 state income tax, of which amount 95 per cent. was due directly or indirectly to the mining industry. Preparations were under way at the year-end to build a spur track through 630 ft. of tunnel to connect the mines and Skinner roaster at New Diggings with the C. & N. W. Ry. at Strawbridge.

Zinc in Foreign Countries

Australia.—In July, 1916, the Zinc Producers' Association Proprietary, Limited, was formally registered in Australia with a nominal capital of £100,000 in shares of £5 each. Producing companies identified with the association are: The Amalgamated Zinc (De Bavay's), Sulphide Corporation, Zinc Corporation, Broken Hill Proprietary, Broken Hill

South, North Broken Hill, Block 10, Block 14, British Broken Hill, Junction North, Broken Hill Junction, Associated Smelters, Electrolytic Zinc Smelters, Mount Lyell M. & R., and the Burmah Corporation.

The Australian output of zinc concentrates—estimated by Mr. W. R. Ingalls in *Engineering and Mining Journal* at 400,000 to 450,000 long tons per annum—will be pooled on the basis of the value of the concentrates, which range from 46 per cent. to 49 per cent. Zn. In September, 1916, a 10-year contract was effected with the British Government for a yearly delivery of 100,000 tons of concentrate on a minimum of £23 per ton for ordinary brands of spelter, and a bonus of £5 for electrolytic zinc. In addition the British government will advance the Australian association £500,000 for the manufacture in Australia of spelter, contracting for an annual output of 45,000 tons of spelter.

Publication was made that United States Steel Corporation began early in 1917 receiving large consignments from Australia, boated to San Francisco, with rail transportation to the corporation's works at Donora, Pa. These works have a capacity for 100,000 tons concentrate per annum, and having no other fixed source of ore supply may be expected to use liberally from the Australian supply.

A further disposal of Australian concentrate product, not provided for, it is believed will be made to Belgian and French smelting interests as fast as they are prepared to utilize it.

Continental Europe.—Under existing war conditions a separation of continental zinc interests is difficult. So far as known the most serious damage to the Belgian smelting industry was the loss of the chimney of the Overpelt works of Beer, Sondheimer & Co., and minor damage to plants near Liege. Later war movements, should the Germans retreat from Belgium, can only be guessed from the extent of destruction elsewhere left behind in other retreats. Many of the works are in the probable line of fire, in such event, and no effort will be made to spare them. If the flow of concentrates from Australia, going to continental Europe before the war, be permanently diverted at its close, Belgian and French furnaces will be the greatest losers. Germany is conceded to be able to produce sufficient ore for internal metal uses, but if dependent wholly upon these that country will be forced from an active participation in the world market.

In Spain the leading zinc works are those of Penarroya and Arnao, in the Provinces of Cordoba and Oviedo, respectively. The minerals treated are principally calamines and blende. These are properly prepared, washed, and finally calcined in the furnaces and the zinc produced is sold in bars, lumps, cakes, and sheets, as well as in manufactured articles. In April, 1915, zinc in cakes was embargoed, and on Jan. 1, 1916, an export tax of $18 per 100 kilos was placed on zinc in pigs, blocks, and waste articles, and the import duty was removed.

According to *Mining Magazine*, the Irtysh Corporation, in Russia, has presented its first annual report.

At the Ridder mine, the sixth level from the Gregorievski shaft is being developed; the shaft has been sunk to a seventh level, and cross-cutting to the lode is in hand. The North shaft, 800 ft. away, has been sunk 90 ft. A third shaft to the south is to be started. The temporary concentration plant treated 13,000 tons of high-grade ore up to Oct., and produced 5100 tons of zinc concentrate and 1600 tons of lead concentrate. This plant will be at work all next year, and in the meantime a new concentrator with a capacity of 200,000 tons per year is to be erected. At the zinc smelter, the first distilling furnace was put into commission in August last, and a second started the end of the year. Four more should be ready during 1917, and the intention is to build 20 eventually.

Austrian prisoners are making spelter at Ekibastus in Siberia.

Canada.—The greater part of the production of zinc ore in Canada is from British Columbia, according to the *Canadian Mining Journal*, Jan., 1917. The ore shipped contains also a varying silver-content, for which payment is made by the smelters, and without which, on account of the import duty to the United States and the long rail haul, it would not in many cases pay to ship. The Slocan mining division produced about one-third of the total output in 1915—Nelson about one-fifth, and the balance came principally from the Ainsworth and Fort Steele divisions.

In Quebec, the property at Notre Dame des Anges, Portneuf County, which is being operated by the Weedon Mining Co., has shipped several hundred tons of ore.

In the same month the *Engineering and Mining Journal* published a synopsis of a report by Mr. Alfred W. G. Wilson on "The Production of Spelter in Canada," indicating that a change would be wrought in 1917 by which Canadian ore could be reduced to spelter within the Dominion. He gives the results of an investigation into the costs of the raw material, required in the industry, based on information obtained in the principal smelting centers of the United States and the zinc mines of British Columbia during the summer of 1916. It also deals with the prospective output of the British Columbia zinc mines, tariff conditions, and the production of electrolytic zinc in Canada. The conclusion of the author is that, so far as the actual operations of a smeltery are concerned, the cost of smelting in the Crow's Nest Pass area or on the Pacific coast would not be made greater than in the Middle Western States; where coal is used for fuel, and with coöperation between all the interests concerned, it could be carried on in Canada with equal or greater economy than elsewhere. The cost in the natural-gas areas in Canada would be greater than in corresponding areas in the United States, but not at all prohibitive. The writer is in accord with previous investigators in concluding that it has not been demonstrated that British Columbia silver-lead-zinc mines are capable of producing enough high-grade zinc concentrates to support a smeltery operating on the Belgian or any similar process. An independent zinc-smelting plant would be handicapped for lack of a silver refinery and would have to consign all lead and silver constituents to the smeltery at Trail or to Helena, Mont., thus curtailing its profits.

The establishment of the new electrolytic plant at Trail and the proposed establishment of the plant at Nelson by the French Complex Ore Reduction Co. have materially altered the situation with respect to a market for British Columbia zinc ores. The process used at Trail is still undergoing development, and the Consolidated Mining and Smelting Co. is not in the market to purchase zinc ores, having an ample supply of its own. As soon, however, as initial difficulties are overcome, it is their intention to purchase ores suitable for treatment in their plant and subject to the market demands for spelter.

The establishment of a zinc-smelting plant in British Columbia at present does not appear feasible on account of the inadequate supply of ores and suitable labor and the high cost of structural materials. Moreover, the retorting process is not especially adapted to treat the complex silver-lead-zinc ores comprising the bulk of the British Columbia output, whereas developments now going on in electrolytic processes give promise of a solution of this problem. If these processes are successful, it may prove to be possible to treat some ores locally in plants of smaller unit size than are practicable in smelting by a retort process.

China.—French Indo-China made shipments of 33,330 tons of zinc last year, of which 17,903 tons went to France, 7825 tons to the United States, and 7602 to Japan, according to a supplement to *Commerce Reports.* The *Mining Journal* gives the production as follows: Sté. Minière de Tonkin, 17,600 tons; Mines de Cho-Dien, 8600 tons; Sté. de Trang-Da, 7200 tons; Sté. de Yen-Linh, 3000 tons; Sté. de Thanh-Moi, 2900 tons.

In 1914 exports were but 19,562 tons. In *Commerce Reports*, Sept. 30, 1916, Consul Lawrence P. Briggs, Saigon, French Indo-China, presented an exhaustive review of the zinc mines of Tonkin. The introductory gives a comprehensive idea of the territorial extent and possible future importance of this field, and is as follows: Zinc is the leading metal produced in French Indo-China. During the past 5 years the exportation of zinc ore from Haiphong has averaged nearly 27,000 tons per year. The customs value of this ore during this period has averaged about $640,000 per year, but the market value has been considerably higher.

Although some zinc has been mined in Annam, and this mineral undoubtedly exists in the interior protectorate of Laos, practically all of that now produced in French Indo-China comes from the protectorate of Tonkin and is exported from the port of Haiphong. The zinc mines exploited at present occupy a strip about 50 miles wide and 100 miles long just above the delta district, a little north and a little east of the center of the protectorate. There are four well-defined zinc regions.

The oldest zinc region of Tonkin is the Tuyen-Quang district near the town of the same name at the junction of the Clear and Gam Rivers. The ore from this group is carried in river steamers down the Clear and Red (Rouge) Rivers and through the canals to Haiphong.

Next in age and in recent years the most productive district is the Thai-Nguyen region above the town of this name on the Song Cau about 50 miles east of Tuyen-Quang. This is the most extensive district, and it is located near the center of the Tonkin zinc fields as they are at present exploited. The ore from these mines is floated in sampans down to Dap Cau, nearly 100 miles, then transferred to river steamers.

On the extreme east is the Than-Moi or Langson region on the upper waters of the Song Thuong and along the railway between Phu-lang-thuong and Langson. The ore from this region is transported by rail to Phu-lang-thuong, where it is loaded on river steamers.

The newest and perhaps the richest of these regions is the Chodien or Bac-kan district, east of the Song Gam, about 50 miles above Tuyen-Quang. The ore from the Cho-dien mines is carried by a private railway to the Song Gam, then by sampans to Tuyen-Quang, whence it is transferred to river steamers.

These four regions include about 30 zinc concessions, of which only 11 are at present in process of exploitation.

In Hunan, Central China, the Shui-ko-shan mine, owned by the Hunan Official Mining Board, produced from 1896 to 1914, inclusive, a total of 111,642 tons zinc concentrate and 45,195 tons lead concentrate. Hunan is one of the provinces of southern central China, and lies on the south side of the Yangtze River. The mine dates back to 1600, being spasmodically operated for 300 years. Recent modern installation has placed this mine in line with methods of mining in other countries.

Bolivia.—Production of zinc reached high mark in Bolivia in 1910, when 11,897 metric tons were exported, declining to 104 tons in 1915, 74 tons to the United States and 30 tons to Great Britian. Large zinc deposits are stated in *Commerce Reports* to exist in various parts of the country.

Japan.—The output of zinc in Japan shows a large increase. According to department reports published by the *Japan Chronicle* the output in 1915 was 23,421 tons valued at $6,456,867, compared with 6553 tons and $682,454 the preceding year, an increase of 257.4 per cent. in quantity and 841.1 per cent. in value.

The Kamioka mine in Hida Province, producing 20,000 tons annually before the war, one-half the output of Japan, has increased its production 30 per cent. The Takata mine will produce 8400 tons, another mine owned by the same company 2400 tons, the Kuhara company 3600 tons, the Yasuda mine 6000 tons per year. These are the larger mines.

Japan has been exporting zinc ore about 10 years, as reported by the *Engineering and Mining Journal* of Jan. 6, 1917. In 1911 the first attempts to produce zinc metal were made, but did not prove very profitable. The war, however, has brought about a complete change of the whole situation, Japan being now a large exporter of zinc metal and importer of zinc ore. The high spelter prices caused by the war have made zinc refining a lucrative business. At the present time, strange to say, Japan exports and imports zinc metal; not only that, but it also exports and imports zinc ores. Besides the figures given for the import of zinc ores and the export of zinc metal, the official statistics give the following items: Zinc ores exported January-September, 1916, 1804 tons, value 145,937 yen; zinc metal imported January-September, 1916, 4800 tons, value 2,819,206 yen.

Great Britain.—The Minister of Munitions, under order of Mar. 23, 1917, placed an embargo on the sale and purchase of spelter. As reported by the *Mining Journal* the order is as follows:

1. No person shall, as from the date hereof, until further notice, purchase, sell, or, except for the purpose of carrying out a contract in writing existing prior to such date for the sale or purchase of spelter, enter into any transaction or negotiation in relation to the sale or purchase of spelter situated outside the United Kingdom except under and in accordance with the terms of a license issued under the authority of the Minister of Munitions.

2. No person shall, as from the date hereof, until further notice, purchase or take delivery of any spelter situated in the United Kingdom, except under and in accordance with the terms of a license issued under the authority of the Minister of Munitions, or sell, supply or deliver any such spelter to any person other than the holder of such a license and in accordance with the terms thereof; provided that no such license shall be required in the case of any sale, purchase, or delivery of such spelter for the purpose of necessary repairs or renewals involving the use of not exceeding 1 cwt. of such spelter.

3. No person shall, as from the date hereof, until further notice, except under and in accordance with the terms of a license issued under the

authority of the Minister of Munitions, use any spelter for the purpose of any manufacture or work except:

(*a*) For the purpose of a contract or order for the time being in existence certified to be within Class "A" in the order of the Minister of Munitions as to priority dated the 8th March 1917, and made in substitution for Circular L. 33.

(*b*) For the purpose of necessary repairs or renewals involving the use of not exceeding 1 cwt. of spelter.

4. All persons shall, in the first 7 days of each month, commencing with the month of April 1917, send in to the Director of Materials (A.M.2.C.), Ministry of Munitions, Hotel Victoria, London, W.C.2, monthly returns of:

(*a*) All spelter held by them, in stock or otherwise under their control, on the last day of the preceding month, specifying the quality thereof.

(*b*) All spelter purchased or sold by them for future delivery and not yet delivered on such last day, specifying the names of the sellers to or purchasers from them, and the quantity and quality, and time and place of delivery in each case, and the position of the spelter at the date of the return.

(*c*) All spelter delivered to them during the preceding month and from whom purchased.

(*d*) All contracts or orders existing on the last day of or entered into during the preceding month requiring for their execution the use of spelter, specifying the purposes thereof and the quality of the spelter to be used.

(*e*) Such other particulars as to spelter as may be required by the Director of Materials.

Notwithstanding the above, no return is required from any person whose total stock of spelter in hand and on order for future delivery to him has not at any time during the preceding month exceeded 1 ton.

5. For the purpose of this order the expression spelter shall mean spelter of all qualities, and shall include sheet and rolled zinc, scrap zinc, hard spelter, dross, zinc ashes, flux skimmings, and zinc dust.

6. All applications for licenses should be made to the Director of Materials (A.M.2.C.), Ministry of Munitions, Hotel Victoria, London, W.C.2, and marked "Spelter License."

NOTE.—Every applicant for a license must state the amount and quality of metal required by him per month, and the use to which it will be put.

Any person acting in contravention of or failing to comply with the above order, or making a false return, will be guilty of an offence under the Defence of the Realm Regulations, and be liable to penalties of fine and imprisonment.

Summary.—During the past year, as during the preceding year, pessimistic writers found space to predict evil for the year ahead. It is unquestionably true that war demands have created a situation in zinc ore and spelter that must eventually be ironed out under normal conditions, but the future will take care of these points. It is enough to learn that the world is full of zinc ore awaiting the need of it, and it is better to assume that new avenues of use will be opened in times of peace that will permit the operation of all the new smelters erected under war pressure and many more. It is refreshing to learn that the United States Bureau of Standards has decided to take up the study of zinc. It is one of the oldest of metals and one of the newest, in that the ancients made limited use of it we to-day know little about. Modern zinc metallurgy is in its infancy, as attested by the wonderful strides of the past 2 years in electrolytic refining methods. There should and will be advanced many additional uses for zinc since it is known to be a product of every country around the world. Perhaps the Government tests in tension, torsion, transverse, cold bend, compression, shearing, and hardness, will blaze a trail that will widen into a broad highway of usefulness for zinc, by awakening the necessity of disposal of a probable surplus product when the world is at peace.

The University of Utah, taking up the necessities of producers of zinc ore with iron-content in excess of 10 per cent., has evolved a process for eliminating the iron and converting a heretofore unmarketable ore into a product of value. Flotation of zinc slimes is no longer an experiment, but to many mines a necessity.

One view of the larger smelting capacity that is generally overlooked was tritely expressed in an interview with George C. Stone of the New Jersey Zinc Co., in the *Engineering and Mining Journal* of Feb. 3, 1917. He said: "I think that we zinc men have been some of the worst sufferers in the last 2 years. There have been compensations sufficient to make up for the large increase in labor costs, but aside from this we have suffered severely from the scarcity of skilled furnacemen. Good spelter men are always scarce, and when the smelting capacity of the country was doubled in a very short time, the lack of experienced men was severely felt. Owing to the shortage, they could get practically what they asked for and they asked frequently. We found considerable difference in the amount of trouble involved in obtaining suitable men in different parts of the country, depending on the proximity of other smelters. The Southwest, where the works are numerous, close together, and were rapidly increasing their capacity, was the worst point. The Mississippi

Valley, where there are fewer works and less expansion, was not so bad, and in the East, where there are no other spelter works, our only trouble was due to the general shortage of labor.

"The scarcity of skilled labor has been a much more serious matter than high wages, the latter being compensated for by the high price of the product. Spelter furnacemen, like poets, are largely born and not made, and the presence of a large proportion of men who do not know the business tends generally to poor work, both in recoveries and in quality of the product. Owing to the labor shortage, the men were very independent and it has been impossible to enforce discipline. The men did not care if they were discharged as they knew they could go to the next works and get an equally good job at the same pay. It is impossible to state in dollars and cents the loss through poor and careless work, but it is very large and is likely to continue for some time after the conditions that have caused it are removed. It is much easier for the men to do things in a careless way which causes losses in recoveries and quality, and it will take a long period of hard times to make them again take proper care. The success of spelter work depends more on the individual care and skill of the men than in almost any other branch of metallurgy, which is my reason for saying that we have suffered more than others."

Metallurgy of Zinc

By W. R. Ingalls

At most smelteries the operating and technical staff was too busy in 1916 making spelter as rapidly as possible to give any thought to improvements in practice, but such concentration fortunately was by no means universal.

Smelters were hampered throughout 1916 by adverse labor conditions. Wages were increased repeatedly, and the more they were increased the worse seemed to become the metallurgical results. As one well-known smelter wrote me, "Wherever I go the situation is about the same. Highest wages ever paid, poorest work ever done, and absolute indifference on the part of the men as to whether they work or not." Some of the older smelters that have the benefit of a relatively stable working force did not apparently suffer very much, but on the front, so to speak, extractions generally fell off very seriously.

Simmonds Retort Discharging Machine

The Simmonds retort discharging machine has continued to give excellent satisfaction at the works of the United States Zinc Co. at Sand

Springs, Okla., and at Pueblo, Colo., the former having 16 and the latter six of them. The work accomplished with these machines is reported to be better than that done by hand. The men prefer them, owing to the arduous work they save and the better cleaning of the retorts that they effect. Although the machine occasionally breaks a retort, furnace records show that such extra breakage as there is, is easily offset by the gain in keeping the retorts clean and lengthening their life. The first of these machines was installed at Sand Springs, where it has now been in continuous daily operation for 18 months without missing a shift and is still in good condition and doing good work. The principal upkeep has been the item of scraper chains, the average life of which is about 100 days. The Simmonds Engineering Co. is hopeful to improve these chains so that a longer life will be realized.

Hydraulic Retort Presses

The Simmonds Engineering Co. has introduced a new hydraulic press, which is now in use at the works of the Kusa Spelter Go., at Kusa, Okla., at the Sand Springs plant of the United States Zinc Co. and at the works of the Bartlesville Zinc Co., at Blackwell, Okla. With the Simmonds press the retort is formed around a stationary core, which is held in place by four bars cast solid with the matrix bushing. The core is bolted to the center, or hub, of these bars. The clay is forced around the bars and forms a bond after passing them and then narrows down to the thickness of the retort wall. This press is regarded by some as being advantageous over other types, inasmuch as it has only one plunger while other types have three, which naturally reduces the first cost, and the wear and upkeep are also less. However, this is not a new idea, early forms of the Dorr press exemplifying the same principle.

Fuel—Coal and Gas

The rapidly increasing cost of natural gas caused smelters to think more than ever about being economical of it. Gas cost of 7 cts. per 1000 cu. ft. is not uncommon nowadays. Nor is the consumption of 65,000 to 70,000 cu. ft. per ton of ore. The only things that can excuse the erection of a natural-gas plant under such conditions, rather than a coal plant, are that it can be built more quickly and costs less money per unit of capacity.

Even the coal smelters were trying to be more economical in the use of fuel, some of them experimenting with different types of producers with that in view. The American Zinc, Lead and Smelting Co. reported material improvement, with indications that still further savings would be made.

The Societa di Monteponi, the largest producer of zinc ore in Sardinia, is doing something new in its construction of a smelting works in Vado bei Savona, which is to have six furnaces of 240 retorts each. These will be fired with the gas of a coking plant. Besides these furnaces, two electric furnaces are being built.

Roasting Furnaces

A new effort to make the Wedge furnace successful for the dead-roasting of blende is to be made at Palmerton, Pa., where a furnace especially adapted for this purpose is in course of erection. The Spirlet furnace, which previously found a foothold in some of the works of the National Zinc Co., and the Grasselli Chemical Co., was installed during 1916 at the Rose Lake smeltery of the Granby Mining and Smelting Co., three of them being built there. In Great Britain, also, this furnace has been commanding a great deal of attention, and it will probably be used in some of the new works in Great Britain and colonies.

At Hillsboro a new Hegeler furnace was built, 20 ft. longer than the standard. Also, an additional hearth was built at the bottom for the purpose of direct firing or to serve as a cooling hearth, as might be deemed best.

In the natural-gas fields, the increasing cost of gas obliged smelters to exercise greater care in the use of it. As a step in this direction the notoriously wasteful Zellweger roasting furnaces were remodeled by the Bartlesville Zinc Co. into Ropp furnaces, with the result of saving 50 per cent. in gas consumption for roasting.

Distillation Furnaces

In the matter of distillation furnaces there is as much uniformity among American smelteries as there is with respect to roasting furnaces. At Pueblo, Colo., there are some Overpelt-Rhenish furnaces. At Peru and Depue, Ill., the furnaces are Siemens-Belgian. At Palmerton, Pa., are the only examples of counter-current recuperative furnaces, the design of their laboratory and superior structure being along Belgian lines. Everywhere else the furnaces of the United States are Hegeler-Belgians, designed either for producer-gas or natural-gas firing, with the necessary modifications according to the fuel. With the Hegeler-Belgians fired by producer gas, in most cases the products of combustion are conducted through properly designed steam boilers on their way to the chimney. When there is a demand in the plant for a great deal of power, as at Peru, La Salle and Donora, this is a very good method of heat recuperation. When the furnace is credited with the coal equivalent of steam generated, the consumption of coal for smelting is reduced to a relatively low figure, but I question the validity of some of the phenomenally low figures that are talked about.

In Europe the Rhenish furnace of one variety or another is becoming the predominate type. The sharp cleavage between European and American practices in distillation furnaces is remarkable. The Europeans have never been interested in our Hegeler-Belgians, while we have never built any Rhenish furnaces except those at Pueblo, which were erected by Overpelt engineers, the firm of Beer, Sondheimer & Co. being at that time interested in the Pueblo plant. Some of our most experienced metallurgists who have been connected with the administration of the Pueblo plant have conceived a strong prejudice against its furnaces. Nevertheless, I am convinced that the Rhenish furnace should receive more respectful consideration by some of our smelters who are operating plants where conditions are favorable to it. Among other things, we ought not to be so complacent about a loss of 2 per cent. of zinc, or so, because the taking off of prolongs for our three daily drawings of spelter does not comport with our labor conditions.

Vertical Retorts

The dream of a good many zinc metallurgists for 50 years was to manage to smelt zinc ore in a blast furnace. We are pretty sure now that it can not be done—that it involves things that are contrary to a law of nature. The next best thing, probably, would be to smelt in vertical retorts; that is, to turn the retorts of our present furnaces from their approximately horizontal position to the vertical. This would greatly reduce the labor of the maneuver—the discharging and charging of the retorts—which is the principal part of the labor requirements in distillation. Instead of ore having to be thrown into a small cylinder, a job that requires extraordinary dexterity, the charge would simply be dropped in; and similarly the residue would be dropped out instead of having to be raked or blown out.

Vertical retorts were the very prototypes of our furnaces (see the primitive Chinese furnaces, the early English furnaces and the Carinthian furnace, the last being a contemporary of the first Silesian furnace). A good many metallurgists tried to modernize the Carinthian furnace, increasing the size of the retorts, improving the arrangement, etc., but nothing useful was accomplished. The charge gave trouble by hanging in the retorts, the gas and vapor could not escape properly, etc. The old difficulties have been completely overcome and, moreover, the reduction of charge has been made a continuous process by the Roitzheim-Remy furnace at Hamborn (Westphalia) if we may rely upon Mr. Liebig,[1] and certainly he is high authority. Unfortunately his article does not give a drawing of the furnace. He describes mechanical features and the method of gas firing, general operation, etc., but not the thing we should most like to know about, namely, the connection of the condenser to the retort. In some of the Roitzheim patent specifications a series of side outlets from the retort by means of upwardly slanting holes—an entirely logical arrangement—are shown. Is this a feature of the furnace at Hamborn? Anyway, it may be accepted from Mr. Liebig that the continuous smelting of zinc ore in vertical retort is an accomplished fact, and the development of the Roitzheim-Remy furnace should be watched carefully.

Briquetting

One of the great problems that confront the zinc smelter is the distillation of excessively fine ore, such as he gets from the flotation mills. Excessively fine stuff is not the best material with which to fill a retort. It is bulky, reducing the retort capacity. The gas and vapor can not readily get out of it. The heat is checked in getting into it. The time is coming when flotation concentrate will be the smelter's main supply of ore, and then he will have to master the problem of it. (Incidentally, this thing does not bother his electrolytic rival, except in the matter of roasting, which is common to both.)

One of the things that ought to be thought about is briquetting. Parker C. Choate has lately been doing some work on this subject, especially with a view to the direct decomposition of zinc sulphide by lime. The chemistry of that reaction is not new. Prost long ago showed that lime decomposition of zinc sulphide took place about as easily as carbon reduction of zinc oxide. This idea does not, however, appeal favorably to the zinc smelter. In the first place he wants to free his sulphur in the easiest possible way for sulphuric-acid manufacture, and in the second place he wants to smelt his retort residue for silver and lead and does not want to have it messed up with calcium sulphide. But Choate's main idea is to make a very dense briquette under great pressure, making a mechanical compound of ore and carbon that will have practically the physical properties of an artificial mineral, which he does by a process of his invention, and there may be something in that which is worth trying. The intimate contact of ore and reduction material, the good heat-conducting property of the compound and the ability to get a suitable

[1] *Metall und Erz*, Mar. 22, 1916.

granularity of charge, even out of excessively fine material, embody principles that are correct.

The preparation of briquettes merely for charging in the form of cartridges, the revival of an ancient idea that is now having some vogue, is an entirely different affair. There are some good features about the notion of charging in that way, but the difficulty is to get the charges into the retort after it has crusted up with slag.

Prereduction

It seems to me that Mr. de Saulles struck an important line when he tried prereduction of his charge before putting it into the retort. The distillation of zinc ore is a stage process. First come off the hydrocarbons of the coal, then the metallic oxides other than zinc begin to be reduced, giving off carbon dioxide as a reduction product, which reoxidizes zinc when the reduction of zinc oxide begins. This is a powerful influence in the formation of blue powder, which occurs chiefly in the early period of distillation. It is not so fatal in the ordinary method of smelting, just by reason of its intermittency, as it is in any continuous process. In the latter it is essential that the preliminary reduction be performed in a separate furnace if excessive blue powder is to be avoided, and electric zinc smelters found that out, just as Salgués indicated they would many years ago.

Reworking Furnace Residues

Much attention was devoted to the subject of re-treating furnace residues. This has become a regular practice at several works. Two methods are in use. Residues containing silver and lead are treated as heretofore, making them available for lead blast smelting furnaces. Residues that are low in silver and lead are burned on Wetherill grates for extraction of the last part of their zinc, which is recovered as zinc-oxide fume. During 1916 oxide plants for this purpose were built at Bartlesville, Okla., at Hillsboro, Ill., and at Donora, Pa., and other places, although some of them have not yet been completed.

The Bartlesville plant (Bartlesville Zinc Co.) is equipped with four automatic filtering machines of Simon, Buehler & Baumann. These machines have not yet been wholly adapted to the purpose, but the Bartlesville people are confident that after a few changes they will do efficient work and will be immensely superior to the old-fashioned bag-house, saving both in first cost and in operation. These machines are also being tried at Palmerton, Pa.

Refining by Redistillation

The practice of refining spelter by redistillation continued at a good many works, and methods were so improved that at some works it became possible to turn out a considerable tonnage of spelter with a purity of 99.93 to 99.95 per cent. zinc. Examination of the residues from such redistillation led to the discovery, through the enormous concentration taking place, of the occurrence of several rare elements. Thus were obtained gallium, indium and germanium, and Dr. Hillebrand, of the United States Bureau of Standards, and several of the universities were supplied with small quantities of these elements.

In Sweden and Norway the refining of common spelter by redistillation in electric furnaces was carried on in a large way, especially at Sarpsborg and Trolhättan. Ore smelting was also done at Trolhättan.

Electrolytic Zinc

Great interest was exhibited in the production of zinc by the hydrometallurgical-electrometallurgical way, following the successful adventure of the Anaconda company under the guidance of Mr. Laist. The Great Falls plant of the Anaconda company was put in operation late in the year. The plants of the Consolidated Mining and Smelting Co. of Canada, at Trail, B. C., were also put into operation. Several small plants were operated, such as those at Baltimore, Md., and Keokuk, Iowa. Plants are in course of construction by the Daly-Judge Mining Co., at Park City, Utah, the American Smelting and Refining Co., at Murray, Utah, and the United States Smelting Co., at Kennett, Cal. None of these plants approaches in magnitude that of the Anaconda company at Great Falls. The Daly-Judge plant will be of capacity for producing 15 tons of spelter daily and is particularly interesting on account of the first trial of rotating cathodes that will be made there. The Electrolytic Zinc Co. of Australia was organized and is planning the erection of a plant in Tasmania for the treatment of ore from Broken Hill.

I believe that this new process has come to stay—that some of the concerns committed to it will be able to meet the smelters on the severest terms. But it is not going to be revolutionary. It is not going to put the smelters out of business, for it is only under favorable conditions that the process is going to be commercial. These conditions are chiefly cheap power, high silver- and lead-content of the ore and good extraction of the zinc. No one company is likely to have all these at their maxima, but there will be a fair number that can strike a good general average. I put less emphasis upon direct zinc extraction than I used to, for it has become clear with progress in the art that undissolved zinc may be burned out of the residue from lixiviation, but that adds to the cost of the process as a whole, and high zinc extraction by direct leaching is to be aimed at as much as ever.

Zinc Burning

The treatment of this residue is an interesting problem that nobody has yet worked out, simply for the reason that it has had to be put aside amid more pressing problems. Given an ore that is yielding 83 per cent. of its zinc, the residue may assay about 20 per cent. Zn, but will be, perhaps, only about one-third of the weight of the original ore. The first idea is to dry this mud, mix it with fine coal and burn off the zinc on a Wetherill grate. This will give a fume that will go to the lead-smelting furnace, the silver-content going partly with the fume, partly with the sinter. Another idea is to smelt directly in a reverberatory furnace, cooling the gases therefrom and collecting the zinc fume. Still another idea is to smelt in an electric furnace, which is easy if the zinc is to be collected as oxide. With an electric furnace the volume of gas to be filtered would be at the minimum and cooling flues and filtering bags would be much smaller than in other cases. Any of these things can be worked out. It is simply a question of what is the cheapest.

Speaking of Wetherill grates, there is being a good deal of attention given to the use of them for burning off zinc simply as a method of concentration. This is an easy process where no attempt is made to collect the zinc oxide of the requisite whiteness for pigment. Our zinc smelters are doing this to win zinc from the residues discharged from their distilling furnaces. Those residues contain so much unburned coal, which is utilized on the Wetherill grates, that it is a cheap process and one that is commercially worth while. Yet it is rather a severe reflection on our distilling that it is worth while. It is something like building a fine ore-dressing works and having a lot of scavengers recovering mineral by buddling the tailings downstream.

The weak point of the Wetherill grate is the manual labor required in running it. It is about the same now as 50 years ago, except that its dimensions have been altered to more favorable measures and in some works it has been elevated, so that less labor is needed in handling the residue.

Fume Collecting

The first thing is to cool the gases. When done as commonly, by passage through iron pipes, they have to be very long to get the necessary superficial area. Why not pass through steam boilers or arrangements like fuel economizers and recover much of the heat in useful form, besides doing the job in a more compact, more efficient plant? I understand that the River Smelting and Refining Co. is working this out at Florence, Colo. Of course there will be problems in preventing deposition of the dust and fume in the coolers, especially around the pipes, but they can be solved.

After the gases have been cooled, the next thing is to filter them. The bag-house is the conventional thing, and there is no doubt respecting its economy and efficiency. This is not to say that it can not be beaten. Even now Simon, Buhler & Baumann are introducing an automatic, mechanical bag-filtering machine, which is being tried at Palmerton, Hillsboro and Bartlesville. It is much more compact than the ordinary bag-house and is claimed to be much more economical in operation, as certainly it ought to be if the upkeep be not too high.

Who can say what part the Cottrell system may not play? What is the reason for the difference of opinion about it at present? At the International smeltery at Miami, Ariz., it works with as near perfection as anything can. At Florence, Colo., where it is being used in connection with the zinc burning, it is an object of "cussing" I understand. Someone—I have forgotten whom—has told me, on the other hand, that for settling zinc-lead fume it is fine; that even the lead and the zinc fume can be precipitated separately. I am inclined to think that at Miami they know what they are doing, and that in other places where the Cottrell system is not acting well, probably it is not being managed properly. I believe the Cottrell system will be a useful thing in the metallurgy of zinc.

PROGRESS IN ORE DRESSING AND COAL WASHING IN 1916

By Robert H. Richards and Charles E. Locke

Acknowledgment.—The authors have been unable to make extended visits to the mills for first-hand information during the past year, and they therefore wish to acknowledge their indebtedness to the following for valuable information supplied: E. S. Bardwell, F. W. Bradley, T. G. Chapman, David Cole, J. V. N. Dorr, D. C. Jackling, T. F. Lennan, Seeley W. Mudd, Arthur Thacher, Arthur P. Watt, N. C. Whitten, Albert E. Wiggin, Ralph B. Yerxa.

General

During the past year flotation has still continued to be the line of spectacular advance in ore dressing. Fine-crushing and grinding machines naturally have received much attention on account of their close connection with the new mill processes brought about by flotation.

Mills of large capacity are noted and capacities have been forced on account of the high price of metals. With the new crushing and flotation improvements the Nevada Consolidated Copper mill is expected to treat 14,000 tons daily, the Ray and Chino mills, 12,500 tons each, and the Utah Copper, the unprecedented amount of 40,000 to 50,000 tons. This last mill has reached 40,000 tons at times already, but at the expense of low recovery. It is probable that in the course of time the tailings made by these comparatively new mills can be re-treated at a profit.

Incidentally, although outside the field of ore dressing, the recovery of copper from oxidized ores by large leaching plants is a noteworthy event. Such plants are illustrated by the Nevada Consolidated, the Utah Copper, the New Cornelia and the Ajo. Sulphuric acid is the usual solvent and scrap iron the usual precipitant. The ores are crushed as coarse as ¼ in. so that percolation may be used.

The new 10,000-ton concentrating mill of the Alaska Juneau Co. is a mile-post in the treatment of low-grade gold ores.

Crushing and Grinding

Rock-breakers.—Symons vertical-disc crushers are still finding favor. The New Cornelia Copper Co. is installing them to reduce from 3½-in.

cube to ¼-in. size in two stages. This reduction could be made in one stage, but it is thought better to use three crushers, one for the first stage and two in parallel for the finishing stage. Where Symons crushers are used to deliver a product directly for concentration, it is poor policy to omit a limiting trommel after them, because there will always be flat pieces, and also coarse stuff whenever the crusher chokes and has to be cleaned out. Such coarse and flat pieces make poor work on the jigs.

For breaker wearing parts, manganese steel now stands well in the lead. Careful tests on manganese and chrome steel for breaker-jaw plates gave results as follows:[1]

	Chrome Steel.	Manganese Steel.
Weight of set, pounds	921	740
Cost, f.o.b. mill	$96.93	$72.62
Tons milled	70,206.20	86,478.70
Cost per ton milled	$0.00138	$0.00084

In another mill chrome-steel plates lasted 48,736 tons while manganese steel from the same pattern lasted 99,451 tons.

Rolls.—On the sticky kaolinized ore at the Buckhorn mine, Nevada,[2] jaw-breakers which were originally installed failed miserably, and were replaced with high-speed rolls having blunt teeth which not only broke up the clay, but also successfully fractured the hard "nigger-heads" occurring in the clay. The 45 by 15-in. rolls with smooth shells, which were used as intermediate crushers, would clear themselves fairly well if one of the roll shells had a channel about 1 in. wide and ½ in. deep machined in it, but it was troublesome to keep the groove in the shells as they wore down. The 6-ft. Hardinge ball mill gave very little trouble with this class of ore after the operators had once learned to judge by sound when the balls were beginning to plaster up on the inside of the mill. By shutting off the feed at this time it took only a few minutes for the coating to be ground out.

For roll shells where the feed is about 1½ in. in size, manganese steel will have at least double the life of chrome steel. For finer-crushing, the difference is not so marked and the advantage lies with the cheaper chrome steel.[3]

Pneumatic Stamps.—These are occasionally found in gold mills. The use of three No. 3 Holman pneumatic stamps at the Babilonia gold mill in Nicaragua has led to the conclusion that they are excellent for coarse-crushing, but the capacity decreases rapidly when using screens finer than 12-mesh; also that they are good machines for small properties when freighting is done by animals, no part being excessively large,

[1] F. E. Johnson, *Eng. Min. Jour.*, **101**, 907 (1916).
[2] P. R. Cook, *Bull. Am. Inst. Min. Eng.*, **117**, 1555 (1916).
[3] D. Lay, *Eng. Min. Jour.*, **101**, 951 (1916).

especially in the No. 3 mill with its built-up mortar box. At Babilonia, each stamp, dropping 145 to 150 times per minute, crushes about 25 tons in 24 hr. through Tyler double-crimped wire screens of 6-, 7-, 8- and 9-mesh. 50.63 per cent. of the product is coarser than 20-mesh, 32.86 per cent. is on 100-mesh and 16.43 per cent. through 100-mesh. This product is further ground in pans for cyaniding.

Application of Crushing Machines.—Millmen are studying the crushing problem, especially the application of ball mills in coarse and intermediate grinding, comparing ball mills, stamps, Chile mills and tube mills and determining the field of each. The use of ball mills seems to be on the increase everywhere.

While crushing can not be said to be standardized, yet the following represents present tendencies:

1. For coarse-crushing preparatory to the later crushing steps, use Blake or gyratory-breakers, the former being favored as less complex. Dodge breakers are practically obsolete.

2. For graded crushing with coarse concentration use rolls alone or Symons disc crusher and rolls.

3. For amalgamating gold ores at 30- or 40-mesh, stamps hold their own in most districts.

4. For table concentration and flotation, ball mills of the Hardinge conical type or the Marcy diaphragm discharge type are gaining. They have entirely upset the old principle of stage-grinding. Fine rolls are giving way, although rolls and Chile mills still have their adherents. Huntington mills, Kinkead mills, and grinding pans, for this and other work, are practically discarded.

5. For sliming for cyaniding, stamps followed by tube mills or conical mills have been nearly standard, but now the ball mill is competing with the stamp. It is a question whether the ball mill will be developed to the point where it will grind from breaker size to slimes in one reduction. The tube mill is holding its own for all sliming work, but even it may be ousted by a short fine-grinding ball mill using small balls. The best maximum feed for pebble tube mills was experimentally settled in South Africa at 3- or 4-mesh, at Goldfield at 16-mesh, at Tonopah at 4-mesh or finer, and at Inspiration at 8-mesh, but it is now claimed that higher duty may be obtained by adding coarser material. The Dome mill uses ½-in. stuff and the Nipissing mill adds a small amount of ¾-in. stuff.

Fine-grinding.—Ball Mills.—Large diameters have appeared for ball mills, up to 8 ft. for cylinders and 10 ft. for cones, and at the same time the length of cylindrical mills has been shortened so that some of the recent cylinders are 5 or 6 ft. in diameter by 16 to 20 ft. long for sliming and 7 or 8 ft. by 10 or 12 ft. for concentration.

The marked advance in ball mills during the year has been due not only to mechanical improvements in these mills, and a greater knowledge of their adjustments such as ball sizes, load, speed, liners, dilution, etc., but also to the use of the closed circuit in connection with mechanical classifiers, such as the Dorr, which has led to large circulating loads and consequent increased efficiency, since the larger the load the faster the ore passes through the mill and the better the chance a particle has to escape when it has reached the desired fineness, without being retained and ground finer. One 6-ft. Dorr classifier will handle up to 1800 tons of sand per day. The compactness of this scheme is shown at the Inspiration mill where, in grinding from 3-in. size to 48-mesh product, the space occupied by the ball mill and classifier figures out 1 sq. ft. for 1 ton ground per day.

Marathon, Hardinge, Chile and Marcy Mills.—The Marathon tube mill using rods instead of balls or pebbles has been before the public for 2 years or more, but has not received much attention until recently. F. C. Blickensderfer[1] has given results of comparative tests made at Morenci, Ariz., on a 5-ft. Chile mill, an 8-ft. by 36-in. Hardinge pebble mill and a Marathon mill 3 ft. in diameter and 7 ft. long. The Marathon mill was of cylindrical shape, mounted on rollers and driven by gear and pinion. It had a corrugated lining of cast-iron plates to prevent slip of rods and was charged with 7000 lb. of rods ½ to 2 in. in diameter and extending the full length of the mill. The machines were all fed with sand which would pass a 4-mesh screen. The results of the tests are given in the following tables:

COST COMPARISON

	Marathon Test No. 1, Per Cent.	Marathon Test No. 2, Per Cent.	Hardinge Mill, Per Cent.	Chile Mill, Per Cent.
Operating labor	13.38	11.21	7.75	11.63
Labor on repairs	12.20	12.27	3.85	7.43
Material on repairs	40.38	49.29	28.40	22.52
Power	34.04	34.23	60.00	58.42

Marathon No. 1 is exceeded in operating costs by	Excess Cost, Per Cent.
Marathon No. 2	19.34
Hardinge	72.56
Chile	15.00

Chile is exceeded in operating costs by	Excess Cost, Per Cent.
Marathon No. 2	3.77
Hardinge	50.04

Marathon No. 2 is exceeded in operating costs by	Excess Cost, Per Cent.
Hardinge	44.59

[1] *Bull. Am. Inst. Min. Eng.*, **116,** 1333 (1916); **120,** 2184 (1916). *Min Mag.*, **15,** 177 (1916).

RECORD OF THE AVERAGE FOR EACH TEST

Type of Mill.	Running Time in Per Cent. of Total Time.	Time Lost, Per Cent.	Total Actual Running Time in Hours.	Tons Dry Feed per Hour.	Tons Pulp per Hour	Per Cent. Solids in Feed.
Marathon No. 1.	94.00	6.00	383.0	9.854	27.60	35.7
Marathon No. 2.	94.25	5.75	200.0	18.333	28.87	63.5
Hardinge........	96.25	3.75	1,455.3	10.166	23.75	42.8
Chilean.........	93.75	6.25	1,401.7	9.875	39.64	24.9

Type of Mill.	Ratio of Solids to Water.	Horsepower Consumed.	Tons Dry Feed per Hp.-hr.	Speed of Mills, R.p.m.
Marathon No. 1.................	1 to 1.8	18.60	0.5316	30.27
Marathon No. 2.................	1 to 0.57	22.50	0.8148	30.10
Hardinge........................	1 to 1.3	56.56	0.1797	29.03
Chilean.........................	1 to 3.0	36.70	0.2691	39.88

AVERAGE OF TEST CONDITIONS

Type of Mill.	Stationary Grinding Parts.					Movable Grinding Parts.					Total Grinding Parts.
	Kind of Stationary Grinding Surface.	Wt. of Stationary Grinding Surface, Pounds.	Life of Liners or Die, Days.	Liners or Die Consumed in 24 Hr., Lb.	Liners or Die per Ton, Pounds.	Charge Used in Mill.	Wt. of Initial Charge, Pounds.	Total Pounds Added During Test.	Pounds Consumed in 24 Hr.	Consumed Per Ton of Feed, Pounds.	Consumed per Ton of Feed, Pounds.
Mar. No. 1...	Iron plates	4,480	82	54.707	0.23130	Iron rods	6,395	2,404	150.64	0.63697	0.86827
Mar. No. 2...		4,480	72	62.256	0.14149		7,124	1,441	172.92	0.39295	0.53544
Hardinge.....	Pebbles	6,740	159	41.761	0.17115	Pebbles	10,175	31,956	527.00	2.16000	2.33115
Chilean......	Die	1,722	63	27.333	0.11533	3 Tires	2,526	None	41.66	0.17620	0.29153

SIZING TESTS

Mesh.	Marathon No. 1.		Marathon No. 2.		Hardinge.		Chile.	
	Feed. Per Cent.	Product. Per Cent.	Feed. Per Cent.	Product. Per Cent.	Feed. Per Cent.	Product. Per Cent.	Feed. Per Cent.	Product. Per Cent.
+4	0.13	....	0.09	....	0.97	....	0.94	....
+6	6.49	....	9.37	0.04	8.43	....	7.71	....
+8	17.12	0.01	21.58	0.81	18.79	0.07	16.49	0.05
+10	13.40	0.28	15.90	4.90	13.86	0.58	11.84	0.10
+14	10.44	2.12	13.55	12.05	10.45	1.95	8.98	1.07
+20	8.51	7.06	11.14	15.55	8.49	3.80	7.18	3.63
+28	8.35	14.77	10.42	16.82	8.40	8.17	7.43	7.75
+35	6.61	14.43	6.96	12.50	6.53	10.45	6.04	9.08
+48	5.30	11.68	3.92	8.53	5.29	11.60	4.80	9.38
+65	3.91	8.72	1.97	5.43	4.10	10.25	3.89	8.53
+100	3.78	8.05	1.15	4.67	3.47	10.40	3.76	8.95
+150	2.46	5.15	0.66	2.82	1.81	6.75	2.58	6.23
+200	1.29	2.67	0.37	1.70	1.04	4.13	1.82	4.21
−200	12.21	25.06	2.92	14.18	8.37	31.85	16.54	41.02

GRINDING EFFICIENCIES BY DEL MAR METHOD ON RITTINGER SURFACE BASIS

	Marathon No. 1.	Marathon No. 2.	Hardinge.	Chilean.
Work units in product	17,525.97	11,231.56	21,315.90	24,753.04
Work units in feed	9,122.83	3,910.38	7,184.30	11,090.35
Work units expended in crushing	8,403.14	7,321.18	14,131.60	13,662.69
Work units expended in crushing corrected for tonnage	107,207.30	143,165.70	60,949.60	88,602.54

The grinding efficiencies were also computed by the Gates crushing surface diagram and the following table gives comparison.

COMPARISON OF DEL MAR AND GATES METHODS

Excess Units by	Del Mar, Per Cent.	Gates, Per Cent.	Numerical Average, Per Cent.
Marathon No. 2 over			
Marathon No. 1	33.54	35.69	34.61
Hardinge	134.80	150.75	142.77
Chilean	61.58	80.29	70.93
Marathon No. 1 over			
Hardinge	75.90	84.81	80.35
Chilean	30.52	32.86	31.69
Chilean over			
Hardinge	45.37	39.10	42.23

The foregoing results show favorably for the Marathon mill. The principle of action of this machine appears to be more favorable than that of a ball mill, since with balls the crushing action is between points of contact, whereas with rods there are lines of contact, and moreover the mass of a single ball is much less than that of a single rod. The rods wear evenly and do not get crossed until they are about ⅜ in. in diameter, when they flatten out or break and some roll up and are discharged. Some, however, remain in the mill and give trouble so that it is necessary to shut down the mill at intervals to remove the worn and deformed rods. The mill is also shut down daily to add new rods. By increasing the size of the rods the feed can be increased up to 2-in. size.

These tests have had the effect of turning attention to what seems to be a very promising grinding machine. Up to the present time the chief criticism has been that it is mechanically defective and incapable of continuous operation. This is unquestionably true, but such troubles can be largely overcome by improved design. Two means of overcoming the difficulty with worn rods are understood to be on trial. One uses a tapered form of cylinder open at the discharge end, which is smaller than the feed end. The other reverses the rotation of the mill occasionally, which automatically discharges the worn rods.

It is admitted that the tests were not entirely fair to the Hardinge mill, which was operated as a pebble mill, and which would have undoubtedly shown up considerably better as a ball mill with proper speed and better ratio of water to solid. However, aside from the efficiency, a very important point was brought out, viz., that the Marathon mill, unlike the Hardinge, will not discharge uncrushed ore, if overfed, but will simply make a product which is uniformly coarser. Also the Marathon product is more granular and even and contains less slimes, which makes it ideal for table concentration. All the work is apparently done on the large particles. Sizing tests on samples taken from the inside of the mill show a consistent gradual reduction from the feed end to the discharge end. The rods are claimed to overcome one criticism that has been made of cylindrical ball mills having peripheral discharge, namely, that the large-sized balls all tend to accumulate toward the discharge end of the cylindrical mill and thus not do the work that they should do on the coarse material at the feed end.

These Marathon mills are being used by the Burro Mountain Copper Co. in New Mexico, and also by mills in Missouri. The following table shows products of Hardinge and Marathon mills in crushing lead middlings from about 10-mm. size.

Mesh.	Marathon Mill			Hardinge Mill		
	Weight, Per Cent.	Lead Assay, Per Cent.	Per Cent. of Total Lead.	Weight, Per Cent.	Lead Assay, Per Cent.	Per Cent. of Total Lead.
+ 6	....	....	....	2.8	1.09	0.4
+ 8	0.6	1.20	0.2	2.9	0.88	0.3
+ 10	3.3	1.32	1.0	4.5	1.30	0.7
+ 14	10.4	1.44	3.3	6.6	1.44	1.2
+ 20	14.7	2.20	7.1	6.5	2.70	2.3
+ 28	16.8	2.80	10.3	8.5	3.20	3.6
+ 35	11.7	6.80	17.5	8.4	5.30	5.8
+ 48	8.5	4.50	8.4	8.5	6.00	6.6
+ 65	5.4	5.00	5.9	6.7	7.70	6.7
+100	5.8	5.50	7.0	9.0	8.70	10.2
+150	4.3	7.40	7.0	7.3	10.60	10.1
+200	2.9	7.60	4.8	4.5	12.20	7.1
−200	15.6	8.00	27.5	23.8	14.50	45.0

Note that with the Hardinge mill the finer sizes assay higher in lead and contain more of the total lead than with the Marathon. The latter slimes only about 60 per cent. as much lead as the former.

Opinions vary regarding the relative merits of the three types of mills —Marcy, Hardinge and Marathon. The Marathon[1] is favored at the Phelps Dodge mills in Arizona. The Miami mill favors Hardinge and the Inspiration favors Marcy.

The Inspiration in its test mill tried the Hardinge and decided in favor of the Marcy, but, like the test above described, it was on a pebble mill which had the disadvantage that it could not handle the coarse feed

[1] D. Cole, *Min. Sci. Press*, **113**, 831 (1916).

as the Marcy ball mill does. The Inspiration is now testing out two 8-ft. by 36-in. Hardinge ball mills in tandem. The first receives breaker feed and uses larger balls; the second uses smaller balls and works in a closed circuit with a classifier to make a product in which all but 1 to 3 per cent. will pass 48-mesh.

The Miami first tried a combination of three 8-ft. by 22-in. Hardinge pebble mills followed by one 8-ft. by 66-in. pebble mill and obtained a capacity of 636 tons per 24 hr. Next, they discarded one of the 8 by 22 mills and changed the other two to ball mills, which increased the capacity to 714 tons. Finally, by also changing the 8 by 66 mill to a ball mill, they got a capacity of 822 tons and at the same time got a finer product. They are now trying one primary 8-ft. mill receiving ¾-in. feed and dividing the product between two 8-ft. finishing mills, using smaller balls and working in closed circuit with classifiers.

The Inspiration is now putting in two 8 by 36 Hardinge ball mills in tandem. The first receives breaker feed and uses larger balls; the second uses smaller balls and works in closed circuit with classifier to make a product with 1 to 3 per cent. coarser than 48-mesh. The Inspiration and Miami ores are practically identical so that the results of these tests will be very valuable.

Hardinge Mill.—The use of the Hardinge conical mill has been extended to the Arkansas zinc district, where at the Hurricane No. 2 mill a 6-ft. by 16-in. Hardinge is used to grind zinc ore for table work.[1]

Another field for the Hardinge mill is indicated by the increased use of small sizes in recovering metal from foundry slag and waste by grinding, screening and table treatment. Its continuous action is an advantage over the intermittent machines which have been used in the past.[2]

These small sizes are in use in Missouri, where the St. Joseph Lead Co. has five 3-ft. by 8-in. Hardinge mills, loaded with small cast-iron balls to grind a lead-iron table middling from 20-mesh to 80-mesh. Each mill grinds about 25 tons per 24 hr. and requires 5 hp.

Stamps and Ball Mills.—For years gravity stamps held their own in competition with other crushing machines and still do for medium-crushing with amalgamation on gold ores, but with the advent of fine-crushing for cyaniding and flotation they are meeting formidable competition. First ousted by tube mills in the very fine-grinding field, they are now threatened by ball mills in the intermediate-crushing field.

Admittedly bulky, expensive in power and having numerous parts and high first cost, the causes of the popularity of stamps have apparently been their ability to effect a large reduction in one operation, their de-

[1] L. L. Wittich, *Min. Sci. Press*, **113**, 385 (1916).
[2] A. F. Taggart and R. W. Young, *Bull. Am. Inst. Min. Eng.*, **110**, 435 (1916). *Iron Tr. Rev.*, **58**, 440 (1916).

pendability and the attachment which millmen have gained for them from continuous use and experience. They are flexible, are obtainable in small units, simple in design and operation and easy to transport. Repairs are easy. The stamps are good amalgamators and are readily adjusted to any kind of ore. Regarding wear of metal no exact comparative figures are available, but as far as conclusions can be drawn from existing data it appears that a properly run ball mill is at no disadvantage in this respect. However, the Dome mill in Canada has found that a simple ball mill with a charge of 28,000 lb. of steel balls will crush 498 tons per day using 113.2 hp., or 0.225 hp. per ton, while it took 80 stamps to crush 800 tons through ⅜-in. screens with a power consumption of 0.3 hp. per ton, and the ball mill occupies one-fifth the space necessary for stamps per ton crushed. The consumption of balls is 0.4 lb. per ton. The mill is now replacing all its stamps with six 8-ft. by 30-in. Hardinge mills and reducing its milling cost 3 cts. per ton. The work is to take 3-in. feed and reduce it to about 10-mesh product.

At Juneau, Alaska, also, ball mills are replacing stamps.[1] The new Alaska Juneau gold mill described later uses jaw-breaker, gyratory-breaker, ball mill and tube mill in sequence.

The new United Eastern gold cyanide mill at Oatman, Ariz., delivers the breaker product to two Marcy ball mills, followed by two short Allis-Chalmers ball pebble mills. This combination works very satisfactorily.

The new Nevada-Packard silver cyanide mill[2] has crushing in four stages but finds no place for stamps. First a No. 5 McCully gyratory-breaker reduces the ore to 1½ in.; then rolls crush it to pass a ⅜-in. trommel; next it passes to No. 1 tube mill 6 ft. in diameter and 5 ft. long, which delivers to Dorr classifier which is in closed circuit with No. 2 tube mill 6 ft. in diameter and 10 ft. long. The capacity of the plant is 100 tons in 24 hr. and sizing tests are as follows:

Mesh.	No. 1 Tube Mill.		No. 2 Tube Mill.		Classifier Overflow, Per Cent.
	Feed, Per Cent.	Discharge, Per Cent.	Feed, Per Cent.	Discharge, Per Cent.	
+ 4	33.9	0.2	0.2	0.0	0.0
+ 10	21.7	0.9	2.5	0.0	0.0
+ 20	9.8	2.3	3.9	0.0	0.0
+ 40	5.6	11.4	17.8	1.6	0.0
+ 60	2.9	10.4	22.8	11.8	0.4
+100	2.5	6.4	20.2	17.8	3.7
+150	2.7	6.9	12.9	16.2	6.8
+200	0.9	2.6	3.5	5.8	5.2
−200	19.6	57.8	15.9	46.2	83.3
	99.6	98.9	99.7	99.4	99.4

[1] *Min. Sci. Press*, **113**, 260 (1916).
[2] H. G. Thomson, *Min. Sci. Press*, **113**, 377 (1916).

An interesting point in this mill is the accumulation of a heavy concentrate in the feed and discharge boxes of the tube mills and classifier. This material assays $2300 gold and $180 silver per ton.

At the Santa Gertrudis mill[1] it has been decided that the two-stage grinding in tube mills was an unnecessary refinement. This mill crushes 1100 tons daily in sixty 1550-lb. stamps with 3- and 4-mesh screens, and passes the pulp to six primary Dorr duplex classifiers, which deliver sand to six primary tube mills, 5 by 16 ft., and slime to twelve secondary Dorr duplex classifiers. These make slime, which is finished, and sand, which goes to four 5 by 20-ft. and two 5 by 22-ft. secondary tube mills, which discharge back to the secondary classifiers. Sizing tests of the product at the various stages are as follows:

STAMPS

	Feed, Per Cent.	Discharge, Per Cent.
+2 in.	0.5	....
+1 in.	18.4	....
+¾ in.	13.8	....
+½ in.	8.0	....
+4-mesh	18.7	4.0
+8-mesh	11.5	16.3
+10-mesh	1.8	7.5
+20-mesh	8.5	14.8
+30-mesh	3.9	8.1
+40-mesh	1.4	4.4
+60-mesh	2.2	6.7
+80-mesh	2.0	6.2
+100-mesh	0.5	2.7
+120-mesh	0.8	3.2
+150-mesh	0.4	1.7
+200-mesh	0.2	2.7
−200-mesh	6.9	21.2

CLASSIFIERS AND TUBE MILLS

Mesh.	Primary Classifier Sand, Per Cent.	Primary Tube Mill Discharge, Per Cent.	Secondary Classifier Sand, Per Cent.	Secondary Tube Mill Discharge, Per Cent.	Secondary Classifier Overflow, Per Cent.
+ 4	13.9	0.2	0.8	1.6	....
+ 8	22.8	4.5	0.5	0.1	....
+ 10	8.6	2.2	0.4	0.2	....
+ 20	20.6	8.5	1.6	0.2	....
+ 30	11.8	10.9	3.4	0.7	....
+ 40	4.7	4.8	3.3	1.0	....
+ 60	8.0	12.1	17.5	10.8	....
+ 80	1.9	10.2	9.6	5.6	....
+100	1.6	5.2	11.4	10.3	3.8
+120	1.5	6.5	17.6	15.5	5.7
+150	0.7	4.0	9.5	11.8	5.5
+200	0.8	5.7	8.4	11.2	9.5
−200	2.5	25.0	15.6	30.7	75.1

Mine rock has replaced Danish flint pebbles in these tube mills, small rocks being added through the feeder and large lumps between 5 and 15 in. being loaded through the manholes once a day. One thousand three hundred pounds of mine rock are required per ton of ore milled. Recent tests with cast-iron balls costing 2.5 cts. per lb. give an increase in capacity

[1] H. Rose, *Bull. Am. Inst. Min. Eng.*, **116**, 1295 (1916).

of 33 per cent. with an increase in power consumption of 33 per cent. The wear of balls is 1.7 lb. per ton milled. The tube mill liners of modified El Oro type are of hard cast iron, last 6 months and cost 2.2 cts. per ton of ore milled.

DeKalb,[1] in discussing stamps and ball mills, raises the question as to whether the psychology of fashion may not account somewhat for the tendency toward ball mills. He also claims that in wet-grinding the ball mill makes more fine slimes and colloids than the stamp, and that the question should be considered as to whether these colloids will be harmful in the subsequent treatment of the pulp.

Marcy Mills.—As an example of the favor shown to this mill by other large companies beside the Inspiration, we find the Braden Copper Co. substituting them for rolls in grinding the undersize of a 1-in. grizzly.[2] Each mill treats 456 tons per 24 hr. and sizing tests of the feed and discharge are as follows:

	Feed, Per Cent.		Discharge, Per Cent.
+38 mm	4	+10-mesh	4
+25 mm	20	+20-mesh	16
+16 mm	24	+40-mesh	17
+ 8 mm	20	+60-mesh	9
+10-mesh	25	+200-mesh	15
−10-mesh	7	−200-mesh	39

Chile Mills.—Although the Chile mill has given way to ball mills, notably at the Calumet and Hecla, still it has its adherents.

A. McClaren[3] believes that a field exists for Chile mills as intermediate grinders, especially between stamps and tube mills. He states the stamp loses its efficiency in crushing finer than ¼-in., although it is actually used for finer work than this. The high-speed Chile mill is used to a considerable extent as an intermediate grinder, but in Mr. McClaren's opinion, where a slime product is desired, the slow-speed Chile mill will deliver more per horsepower used, at a smaller cost of upkeep, than either the stamp, the high-speed mill or a combination of both. He cites the following examples. One mill with ten 1440-lb. stamps crushes 80 tons per 24 hr. from 2-in. size through No. 12 Ton-cap screen, using 34 hp. The stamp product contains 25 per cent. passing 200-mesh, which is taken out by the classifier ahead of the tube mill. The tube mill, 5 by 16 ft., grinds the remaining 75 per cent. through 200-mesh, using 40 hp. One horsepower in the stamp accounts for 2.352 tons, in the tube mill 1.5 tons and in the combined stamp and tube mills 1.081 tons. In another mill using three Lane slow-speed Chile mills making 8 r.p.m., 147 tons of 2-in. ore are crushed per 24 hr., using 36 hp. Forty per cent. of the product will pass 200-mesh. One horsepower crushes

[1] *Min. Sci. Press*, **113**, 339 (1916).
[2] R. E. Douglas and B. T. Colley, *Eng. Min. Jour.*, **101**, 315 (1916).
[3] *Eng. Min. Jour.*, **101**, 15 (1916).

4.01 tons, or nearly twice as much as the stamps above, and at the same time yields more finished product.

In regard to high-speed Chile mills an instance is given of 1050-lb. stamps on fairly soft ore crushing 8.5 tons per stamp from 1½ in. through a No. 4 screen using 2.4 hp. per stamp. Twenty per cent. of the product will pass 200-mesh. One horsepower thus crushes 3.541 tons. The high-speed Chile mills following the stamps each crush 75 tons per 24 hr. through a 16-mesh screen and 30 per cent. of the product will pass 200-mesh. The mills use 35 hp. each and thus 1 hp. accounts for 2.142 tons ground. In the combined two stages 1 hp. has reduced 1.335 tons and 44 per cent. will pass 200-mesh. The remaining 56 per cent. is finished in tube mills, 5 by 22 ft., each handling about 95 tons and using 60 hp., or 1 hp. grinds 1.583 tons. In the entire process 1 hp. makes 0.724 tons of finished product, of which 95 per cent. will pass 200-mesh. On a harder ore a 10-ft. Lane slow-speed Chile mill running at 8 r.p.m. reduces 40 tons per 24 hr. from 1½-in. size to a product of which 53 per cent. will pass 200-mesh. Twelve horsepower is used or 1 hp. reduces 3.333 tons.

Although there is apparently much loss of time in changing the wearing parts of a Chile mill (maximum of 6 days every 7 months for chrome-steel tires and manganese-steel track), still if all the time lost by stamps in changing shoes, dies, screens, tappets and cams were added up, the total would exceed that for Chile mills.

The Chile mills still hold their own in the porphyry copper and zinc mills which are under the Jackling management (Utah Copper, Ray, Chino, Nevada Consolidated, Butte and Superior) since it has been found that for grinding to a fineness where from 10 to 30 per cent. of the material remains on a 48-mesh screen nothing gives better results than dry rolls followed by wet Chile mills. It is true that the above plants use ball and pebble mills, but they may be considered as an adjunct to the Chile mills to be applied where grinding is desired to a point where all will pass 48-mesh or finer. These plants appear to make no distinction between cylindrical and conical mills, although a 7 by 10-ft. cylindrical mill is fairly standard with them.

Speed and Pulp Dilution on Ball Mills.—It has been found, in the case of Hardinge conical mills at least, that a reduction of speed is an advantage. On 8-ft. by 24-in. mills, increased capacity and less horsepower is shown at about 20 r.p.m. instead of 27 to 30.

The same thing is shown at Anaconda on the Hardinge mills, originally installed as 10-ft. by 48-in. pebble mills but changed by wood lagging and manganese-steel lining of cascade type to 7.5 by 72-in. ball mills. These modified mills when running with a 20-ton ball load at a speed of

23 r.p.m. take 225 hp. and crush about 225 tons per day from 2 mm. through 1/4 mm. By reducing the speed to 15 r.p.m. the same tonnage is crushed, the power is reduced to 135 hp., the ball consumption is reduced 30 to 40 per cent. and it is expected that time will show a considerable increase in the life of the liners.

It has also been found advantageous to reduce the water in the Hardinge mills, and improved results are now reported to be obtained on siliceous ores with a feed containing 25 to 33 per cent. moisture.

The inference is that at the higher speeds and more dilute pulp the balls or pebbles are doing considerable grinding on one another instead of on the ore. The Inspiration mill recognizing the necessity of controlling the pulp dilution for highest efficiency in their Marcy grinding circuit,

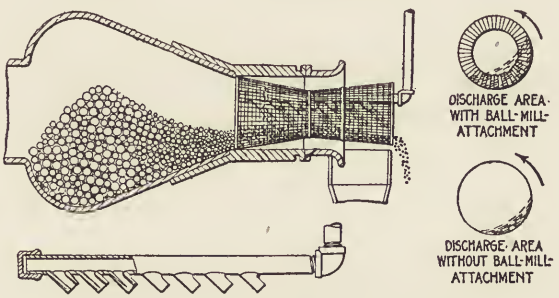

FIG. 1.—Screen discharge for Hardinge mill.

use a hydrometer in the circuit which controls a solenoid-operated butterfly valve to admit whatever water is necessary.

Screen Discharge for Hardinge Mills.—The capacity and efficiency of a 6-ft. Hardinge conical ball mill and an 8-ft. Hardinge pebble mill have been increased at the Tough-Oakes mine by the use of a rotary screen discharge and spray pipe as shown in the figure. The real effect of this device appears to be to increase the rate of discharge of the mill and thus remove more oversize ore and pebbles to be returned for re-grinding in the more efficient large-diameter part of the mill. Incidentally, this device raised the line of discharge so that the pebble load was increased from 8500 to 11,500 lb. The following table sets out the advantages of this device.[1]

Pebbles, Balls and Liners.—The Britannia lining used in the 7 by 12-ft. tube mills in the Britannia mill consists of 5-in. rail sections set on end in neat cement with short pieces of worn-out drill steel in the interstices. The secret of success in placing this lining is that as the cement is placed on the smooth clean lining and the rails imbedded and grouted the tube

[1] C. Spearman, *Eng. Min. Jour.*, **101**, 691 (1916). *Min. Mag.*, **14**, 292 (1916).

COMPARISON OF RESULTS

	Average of 3 Months without Device.	Average of 5 Months with Device.	Increase or Decrease, Per Cent.
Average mill tonnage per day, total time	82.68	102.27	23.7 incr.
Actual horsepower required	40.00	35.00	12.5 decr.
Average mill tonnage per day, actual time	90.62	110.41	21.8 incr.
Actual kilowatt-hour per ton of ore	7.94	5.71	28.1 decr.
Ball consumption per ton of ore	2.45	1.80	26.5 decr.
Pebble consumption per ton of ore	16.15	3.94	....

is turned gradually until in from 3 to 5 days a half-circle has been made, by which time the cement has set so firmly that the rails do not fall out. These tube mills are given a retarded discharge by means of a back worm. The grinding is done by selected mine rock taken off the picking belts.[1]

The silex tube-mill lining for the 5 by 22-ft. mills at the Liberty Bell mill have ten rows of longitudinal cast-iron ribs, or one rib for every three rows of silex blocks. Such linings last 3 years.[2]

The material used in lining a 5 by 22-ft. mill includes 900 silex blocks averaging 4½ by 5 by 8½ in. and weighing approximately 13 lb.; also 19 cu. ft. of Portland cement, 19 cu. ft. of clean sand and ten rows of 50 pieces of hard cast-iron ribs, which are given a taper, measure 1¾ by 2 by 4½ in., are 47½ in. long and weigh 110 lb. each. Two men line the mill in three shifts. The lower half is lined in one shift. Live steam is then turned in for 8 hr., followed by 8 hr. cooling by draft. Next the mill is given a quarter-turn and one-quarter more of its lining put in, followed by the same heating and cooling. On the third day the lining is completed and is afterward steamed for 12 hr., loaded with pebbles and put into service. The ribs are laid in mortar only and no bolts are used in the lining. When necessary to increase the rate of setting of cement mortar, soda ash is added to the cement.

To avoid the loss of time in installing tube-mill liners of silex, A. Del Mar[3] suggests the use of cast-iron frames, eight sections to the circumference of the mill, in which pebbles are cemented months in advance so that the cement will have time to harden thoroughly. Such frames can be easily and quickly fastened into the mill when re-lining is necessary.

For grinding in ball mills chrome-steel balls are the best. Manganese-steel balls will last slightly longer, but their extra cost will prevent their use until such a time may come that the cost of manufacture will be reduced to a point where they can compete.

Many plants are using cheap cast-iron balls in the small sizes, although for large sizes, 4 and 5 in. steel balls are still preferred as being less liable to break.

[1] T. A. Rickard, *Min. Sci. Press*, **113**, 693 (1916).
[2] A. J. Weinig, *Eng. Min. Jour.*, **102**, 27 (1916).
[3] *Eng. Min. Jour.*, **101**, 214 (1916).

Trials of manganoid chrome-steel balls and flint pebbles in Hardinge mills at Lake Superior have brought out the interesting point that on soft copper amygdaloid rock the consumption of each is about the same, but on hard conglomerate the flint pebbles show much lower costs per ton ground, although of course the capacity of the mill is less.

The experience of the West End mill at Tonopah[1] in replacing in their 5 by 15-ft. tube mills the 6-ton load of Danish pebbles with 6 tons of manganoid steel balls, has shown that the power required increased sharply, but the power per ton ground decreased. This saving in power was overbalanced by the greater cost per ton for the steel balls. However, by reducing the diameter of the mill to 3 ft. the tonnage was further increased and the power reduced one-third. Local chalcedony pebbles give a consumption per ton of ore which is 20 per cent. greater than that for Danish pebbles, but the total cost per ton of ore ground is 20 per cent. less than that for Danish pebbles. Komata shell liner plates last 22 months, angles 6 months and filler bars are not worn at all. This liner cast in a local foundry costs 2 cts. per ton ground, which is one-third the cost with smooth liners.

The two tube mills at the new Nevada Packard mill use Danish pebbles mixed with a large proportion of selected rhyolite ore, although it is planned to substitute local balls in the No. 1 mill. Forbes white-iron liners are used and last 8 months. These liners are spaced so as to allow for the removal of a single section when worn. The discharge screens are 4 ft. in diameter, made in two sections. Ribs on the discharge side of these screens act as lifters and assist in a rapid discharge. Reverse screw discharges are not used, as they reduce the area of discharge and consequently the capacity. The scoop feeds have removable plates on the outer faces to allow inspection of the faces. They are also fitted with white-iron digging lips, bolted to the frames, to take the wear. These lips last 8 months and are easily replaceable.

Installation of Tube Mills.—Valuable ideas on the unloading, mounting and starting of new tube mills have been given by C. Labbe.[2]

Theory of Crushing.—The Kick vs. Rittinger controversy (see previous volumes of MINERAL INDUSTRY) has continued. Del Mar and Stadler[3] have discussed the matter, the former favoring Rittinger as the result of some experimental work, and the latter favoring Kick.

It has remained, however, for Prof. J. W. Bell to publish finally the results of the extensive investigations at McGill University.[4] Lack of space forbids the discussion of this in detail, but the following table

[1] J. A. Carpenter, *Min. Sci. Press*, **113**, 197 (1916).
[2] *Eng. Min. Jour.*, **101**, 777 (1916).
[3] *Bull. Am. Inst. Min. Eng.*, **110**, 515 (1916).
[4] *Can. Min. Inst.*, **19**, 151 (1916). *Bull. Am. Inst. Min. Eng.*, **122**, 171 (1917).

shows a few of the results obtained. The conclusions from this work, that for a given rock there is a constant relation between the power applied and the crushing effected, and that the Rittinger theory conforms to this relationship while Kick's law does not, corroborates Gates' experimental work and at the same time appears definitely to settle this long-disputed question.

RESULTS OF CRUSHING TESTS

Machine.	Diameter, of Feed, Inches.	Work Done per Apparent Effective Horsepower.	
		Stadler Energy Units	Rittinger Surface Units.
Gyratory-breaker	3.500	710.0	947
Dodge breaker	1.200	520.0	1,030
Rolls	0.500	286.0	1,128
Rolls	0.290	138.0	1,000
Rolls	0.180	68.0	1,022
Rolls	0.110	89.0	1,187
Rolls	0.070	52.0	823
Rolls	1.000	623.0	1,198
Rolls	0.700	472.0	1,192
Rolls	0.460	272.0	1,097
Rolls	0.300	190.0	1,002
Rolls	0.190	150.0	1,115
Rolls	0.120	109.0	1,054
Rolls	0.080	82.0	1,028
Rolls	0.050	77.0	1,137
Rolls	0.030	77.0	1,250
Huntington mill	0.031	55.0	1,590
Huntington mill	0.020	47.5	1,860
Huntington mill	0.014	45.5	2,030
Huntington mill	0.009	34.2	1,970
Huntington mill	0.007	28.1	1,910
Huntingon mill	0.005	20.2	1,800

Screening, Classifying and Settling

Screening.—Where a bar grizzly is objectionable on account of lack of mill height and its inability to screen clayey ore, a horizontal chain grizzly may solve the problem and at the same time serve as a feeder for the breaker.[1] At the Rowe iron mine, Minnesota, such a grizzly made of old steam-shovel chains has been found very satisfactory. Each chain is mounted on a separate pulley and has a different longitudinal speed from that of its neighbors, which acts very effectively in disintegrating the ore. Where finer-screening is desired, fixed longitudinal bars are set between the chains.

For fine wet-screening, the Maxton screen is claimed to have shown its ability by actual plant work to compete with classifiers. It is a revolving cylindrical screen mounted on rollers and having inside longitudinal angle-iron lifter bars. An inside feed pipe delivers the wet pulp in a very thin layer on the interior of the screen; the undersize is washed

[1] J. C. Barr, *Eng. Min. Jour.*, **101**, 599 (1916).

through, while the oversize is carried up by the lifter bars until it slides off toward the center axis of the screen into a long interior trough.

The art of screening or sizing, including sizing by air and water, as applied not only to ores, but also to all sorts of commercial products, has been very thoroughly described and discussed by E. S. Wiard.[1] The article goes very fully into both the practical and the theoretical side.

Testing Sieves.—The U. S. Bureau of Standards, after thorough investigation, has announced its standard screen scale for testing sieves. This scale is based on the Rittinger ratio of the square root of 2 or 1.4142 for screens between 1 and 8 mm., and the fourth root of 2 or 1.1892 for screens between 1 and 0.044 mm. Thus the scale goes upward 1, 1.4, 2, 2.83, 4, 5.66 and 8 mm., and downward 1, 0.85, 0.71, 0.59, 0.50 mm. etc. The Bureau also announces that it is prepared to certify sieves on a commercial basis.

The Rittinger scale based on 1 mm. as a starting point is logical, but it is unfortunate that it should be advocated at this time when many of the mills have adopted the Tyler standard screens which, while having the same ratio, start at 1.165 mm. instead of at 1 mm.

Testing sieves as fine as 350-mesh, made of vanadium bronze wire, are now obtainable from the Multi-Metal Separating Screen Co. of New York.

Classifiers.—For classifying sand from slime in connection with grinding and cyaniding, the mechanical type of classifier, as illustrated by the Dorr, Akins and Federal-Esperanza machines, now has the field, the first-named being perhaps the most popular.

The relative advantages of these three machines have been summarized by E. S. Wiard in his discussion on grading.[2] In power requirement he puts the Akins as the highest consumer and the Federal the lowest, although all three take little power. The Federal has the highest capacity. The Dorr requires the most attention and the Akins the least. The Akins has the most wear and tear, the other two being about equal in this respect. The Akins starts easily when clogged; the other two must be dug out. The cleanest sand product is obtained from the Akins, the poorest from the Federal and the Dorr is little better. The Akins also gives the cleanest slime product and the Dorr the poorest.

As to the dividing point between sand and slimes, the Dorr has a maximum limit at about 28-mesh for efficient work. At this size the sand product may contain as much as 50 per cent. of material finer than 28-mesh, while at 48-mesh this is reduced to 25 per cent., at 100-mesh to about 20 per cent., and at 200-mesh to a still lower figure.

[1] *Met. Chem. Eng.*, **14**, 91, 191, 383, 529, 575 (1916).
[2] *Met. Chem. Eng.*, **14** 91 (1916).

The Dorr people have recently developed a bowl which is placed on the feed end of their classifier. The bowl receives the original feed and is provided with a set of rakes like the Dorr thickener, which move the heavy feed to the center and discharge it to the classifier below. The overflow from the periphery of the bowl is slimes, and by their partial removal in this way the classifier does better work and is susceptible of finer adjustment. The following sizing tests give results from the Golden Cycle mill, Colorado, where a standard Dorr classifier handled 275 tons of feed in 24 hr. and yielded a slime product with 24 per cent. solids while the Dorr bowl classifier handled 400 tons and gave slimes with 23 per cent. solids.

Mesh.	Dorr Standard.		Dorr with Bowl.	
	Sands, Per Cent.	Slimes, Per Cent.	Sands, Per Cent.	Slimes, Per Cent.
+30	4.5	....	5.5	....
+40	16.5	....	15.0	....
+60	28.5	....	30.5	....
+80	8.0	....	9.0	....
+100	10.0	1.0	15.5	....
+150	18.0	1.0	17.0	1.0
+200	5.5	11.0	3.0	7.0
−200	9.0	87.0	4.5	92.0

To accomplish the same result in increasing the efficiency of the Dorr classifier and reducing the percentage of slime in the sand product, A. E. Drucker[1] suggests the use of a spitzlutte at the feed end to keep out much of the slime. An apparatus along this line is reported to have been used at the Homestake mill.

Another combination of mechanical and hydraulic classifier is reported by M. G. F. Sohnlein[2] to be used in a Bolivian tin mill. It consists of a hopper-shaped hydraulic classifier mounted alongside of, and delivering spigot product to, a Fleming dewatering wheel. The sand product from the dewatering wheel contains less slime than did the spigot product from a hydraulic classifier previously used. It would seem to the writers that this combination would not be capable of yielding any better results than a properly designed hydraulic classifier treating a deslimed feed, but it may have an advantage of using less water and of less dilution of the overflow slimes.

Instead of mechanical classifiers, the St. Joseph Lead Co. in Missouri prefers Caldecott cones for dewatering jig and table concentrates and tailings.[3] These deliver a spigot product on tailings with only 28 to 30

[1] *Min. Sci. Press*, **112**, 433 (1916).

[2] *Bull. Am. Inst. Min. Eng.*, **112**, 715 (1916). *Min. Eng. World*, **44**, 1049 (1916). *Met. Chem. Eng.*, **14**, 538 (1916). *Eng. Min. Jour.*, **102**, 182 (1916).

[3] L. A. Delano, *Eng. Min. Jour.*, **102**, 27 (1916).

per cent. moisture and on the galena concentrates with only 11 per cent. moisture. The overflows are free from material coarser than 150-mesh. Shovel-wheel dewaterers, formerly used, carried considerable coarser sand into the slime overflow product.

A form of dewatering cone called the Allen Automatic Cone classifier is used at the Old Dominion copper mill for dewatering vanner feed, and is being tried out elsewhere.[1] It consists of an outer cone and a central feed cone open at its bottom. Sand accumulates in the former up to a certain level, when further accumulation restricts the opening at the bottom of the feed cone, causes the water to rise in the feed cone, and thus lift a float which operates a lever that opens the ball valve forming the spigot of the outer cone. A little sand flows out, the water level drops and the float closes the valve. This apparatus may have a future.

Slime Settling.—While the Dorr classifier has been gaining in the concentrating mills, the Dorr thickener has made a more remarkable record. Originally designed for cyanide work, it has now displaced cones and other forms of settlers and is almost the universal device for all kinds of dewatering and thickening such as dewatering pulp before tables, vanners or flotation, dewatering flotation concentrates before filtering, and dewatering tailings for recovering the water or for obtaining a thick tailing for storage. It has a great range of work from 28-mesh tailings and 48-mesh concentrates down to almost pure colloids, and it varies in size from 2 ft. up to 200 ft. in diameter, the latter size being installed at Inspiration for handling 100-mesh tailings, and consisting of a reinforced-concrete tank or pond. The mechanism is driven in this case by a 5-hp. motor geared to a single traction wheel running on top of the circular wall.

Where floor space is valuable and economy of installation desirable, the tray type of Dorr thickener may be used, either the connected and open forms where the same material is being treated in the tank and tray, or the closed form where the tray and tank compartments receive different products.

When used for flotation concentrates, there has been in some installations considerable loss from froth and fine slime passing into the overflow. Deep circular baffles reduce this loss, or if the overflow water is returned to the flotation cells, there is no loss. Some plants have had to increase their thickening capacity to 200 per cent. above the original estimate in order to avoid high losses in this way. On account of the settling characteristics of various pulps, depending chiefly on the amount

[1] J. W. Crowder, *Eng. Min. Jour.*, **102**, 507 (1916).

and character of the colloids, it is impossible to determine exact areas required in any special case, but the following figures are average:

	Square Feet per Ton of Solids per Day.
Unclassified slime in cold water without electrolyte	8 to 15
Classified slime in cold water without electrolyte	10 to 20
Copper flotation concentrate without electrolyte	30 to 40
Zinc flotation concentrate without electrolyte	10 to 15
Lead flotation concentrate without electrolyte	10 to 15

Theory of Settling.—Of special importance in connection with the use of Dorr tanks and similar slime-settling devices is the laboratory method of determining the capacity of such tanks worked out by Coe and Clevenger.[1] The only apparatus necessary is a vertical tube with side outlets at regular intervals for drawing off samples of the pulp during the settling process. In settling slimes, five stages or zones may be distinguished: (1) The bottom zone of sand; (2) the next zone where the flocs are in contact; (3) a transition zone; (4) a zone where the flocs are not in contact with one another, the density being the same as in the feed; (5) a top zone of clear water. During settling, zones (2) and (5) are constantly increasing and zone (4) is decreasing until the critical stage is reached where zones (3) and (4) disappear. Any further action takes place in zone (2), which may decrease somewhat due to compacting of the flocs and accompanying squeezing out of the liquid.

It is possible, by taking samples at various levels in a testing apparatus and determining their densities, to figure mathematically the rate at which the solids move downward and the water is squeezed out upward and thus get the capacity of the settling.

The following summarizes the results of this slime settling investigation.

1. In thickening pulps which are to be discharged at a consistency such that the discharge is in the form of a free settling pulp, the depth of the tank is of no importance provided it is not so shallow as to be affected by the agitation from the feed or by the fluctuations in the amount and character of the feed.

2. When thickening pulps to a consistency where it is necessary to expel fluid from the compacted flocs, sufficient capacity must be given the tank, by increasing either the depth or diameter, so that the pulp will be retained the necessary time to thicken or compact to the required density, and at the same time allow sufficient storage to compensate for fluctuations in the feed and discharge.

3. The consistency of discharge possible may be closely determined

[1] *Bull. Am. Inst. Min. Eng.*, **111**, 597 (1916). *Met. Chem. Eng.*, **14**, 398 (1916). *Min. Sci. Press*, **112**, 414 (1916).

by allowing a cylinder of thick but free-settling pulp to settle, taking readings of a few hours up to the point where settling practically ceases.

4. The required area may be computed from the formula:

$$A = \frac{2000}{24\left(\frac{62.35R}{F-D}\right)}.$$

A is the area in square feet required to thicken 1 ton of 2000 pounds of solids to a consistency in the discharge D (parts fluid to 1 part solid by weight) per 24 hr. F is the ratio of fluid to solid in the pulp tested. R is the rate of settling in feet per hour of a free-settling pulp of the consistency of F. Actually a series of settling rates R is taken on pulps ranging in consistencies F from that of the proposed feed to the thickest free-settling pulp. The value used for D is the ratio in the thickest pulp that can be economically obtained.

5. The required depth of the thickener may be ascertained by computing the capacity of the thickening zone to contain a supply of solids equal to the total capacity of the tank for the number of hours required to thicken the pulp to the density required in the discharge, and to this depth adding an allowance for the lost space due to the pitch of the drag in the thickener; also from 1½ to 2½ ft. for depth of feed and a further allowance for storage capacity when the discharge may be closed.

Coe's and Clevenger's work has been used by P. W. Avery[1] in obtaining settling data and making the computations for solving the filtering problem in a cyanide plant. He demonstrates the importance of efficient settling of slimes as the cure for most filter troubles. It is generally found that when a filter is not working at the expected capacity, the trouble is due to too dilute pulp, that is, pulp containing more than 50 per cent. liquid by weight, which is the maximum limit usually set for good filter work. The sure remedy is to increase the thickener capacity, although a certain amount of relief is obtainable by the use of an intermittent discharge in place of a continuous discharge on the thickener.

The theory of slime settling has been discussed in great detail by E. E. Free and O. C. Ralston. The former[2] goes more into theory and covers colloids and suspensions, flocculation and deflocculation, effect of temperature, the free and compacted stages or conditions of settling and the effect of fine particles in filtering and on the porosity of the resultant slime cakes. The latter[3] goes more into the practical side, giving results of settling tests, discussing colloidal chemistry and the practical settling, filtering, flocculation, deflocculation and differential separation of slimes and the effect of electrolytes thereon. Both of these articles are too lengthy to be summarized in the space here available.

[1] *Min. Sci. Press*, **113**, 738 (1916).
[2] *Eng. Min. Jour.*, **101**, 249, 429, 509, 681, 1068, 1105 (1916).
[3] *Eng. Min. Jour.*, **101**, 763, 890, 990 (1916).

Hand-sorting, Jigs and Tables

Jigs.—The Neill jig (see Mineral Industry, **23,** 826) is making a field for itself on California gold dredges where it recovers gold and auriferous black sand and finely divided quicksilver which escape the riffle tables. The jig concentrates are run through a Hardinge mill to brighten the gold and then pass over a shaking amalgamator followed by a silver-plated amalgamated plate. Results indicate that this arrangement adds from 5 to 20 per cent. to the total gold saving of the dredge, this added saving representing gold that formerly was lost. Where the gold is not rusty the Hardinge mill is unnecessary.[1]

The Richards pulsator jig has shown up remarkably well in comparison with Harz jigs for treating tungsten ores in Boulder County, Colorado, and has already been adopted in some of the mills.

Tables.—Butchart riffle tables are continually gaining in favor in all districts. A new Wilfley riffle somewhat similar to the Butchart is now on the market. The Butchart tables are now almost universally used in the Missouri lead mills, where they give great satisfaction in treating unclassified feed ranging from 3 mm. to 150-mesh. This coarse feed causes considerable wear on the linoleum tops and wood riffles, so that concrete decks and oak riffles are desirable. A new departure in this district is to use the Butchart tables for cleaning jig and table concentrates to eliminate any free sand. Very good results are reported.

The Senn Pan Motion Concentrator is a form of vanner which has been tried out by the Phelps Dodge Co. and the Old Dominion Co. in Arizona. The former reports that the machine compares favorably in extraction with the Frue or Johnston vanner, but its chief advantage lies in its capacity, which is two to two and one-half times that of the Frue or Johnston vanner. Thirty of these machines have been installed in the Burro Mountain Copper Co. mill to treat flotation tailings.

The relative advantage of glass of various fluted and frosted forms as compared with wood for the surface of circular and rectangular slime tables treating Cornish tin ores has formed a prolific source of discussion during the past year.[2] While the tests made to date are somewhat contradictory and therefore not entirely conclusive, still the evidence indicates that there may be considerable virtue in the glass surface.

Amalgamation, Magnetic, Electrostatic, Pneumatic and Centrifugal Processes

Magnetic Separation.—Wetherill magnets form the backbone of the new Empire Zinc mill at Hanover, N. M., for separating magnetic zinc

[1] L. H. Eddy, *Eng. Min. Jour.*, **101,** 207 (1916). *Min. Mag.*, **14,** 175 (1916). H. D. Smith, *Min. Sci. Press*, **113,** 202 (1916).

[2] W. M. Martin, W. H. Trewartha-James and others, *Min. Mag.*, **14,** 10, 32, 88, 90, 93, 154, 271, 332, 333 (1916). *Met. Chem. Eng.*, **14,** 399 (1916).

sulphides and oxidized zinc ores, mostly carbonates, from non-magnetic limestone and galena. The feed is closely sized, giving eight sizes between 10- and 150-mesh.[1]

The Weatherby table has received very little publicity, although it appears to be a machine of considerable merit for certain purposes. It is a combination of table and electromagnet, being practically a Wilfley table with magnets suspended from above and having their poles almost in contact with the table top. It is used with much success at Edwards, N. Y., for separating magnetic zinc blende from iron pyrite, making a separation that can not be obtained on an ordinary table. Mechanically it is not the equal of standard tables, but this is a matter that can be easily remedied.

Flotation

Growth.—This process has continued its remarkable record. Estimated tonnage treated by flotation during 1916 is between 30 and 35 million tons, with the prospect of a 50 or 100 per cent. increase in 1917. Of this amount it is estimated that about 13 million tons in 1916 were under Minerals Separation licenses.

This increased use is due to a greater and more widespread knowledge of the practical application of the process rather than to further light on why it works.

The operators are beginning to realize that there is a great field for small, simple grinding and flotation plants which can be erected cheaply and do efficient work on small mines or old dumps.

Leaving out of consideration the extension of flotation that is taking place all over the world along the standard line of separating base metal sulphides from gangue, the following list shows what has been accomplished in unusual or unexpected lines: (1) Replacing cyanide on gold ores. (2) On gold ores at Mt. Morgan and in Rhodesia. (3) Experimentally on South African gold ores. (4) On silver minerals in the low-grade ores at Cobalt. (5) Flotation of flour gold. (6) On mixed copper sulphide and oxide ores and on lead and copper carbonates, although the including of all non-sulphides is still a remote possibility. (7) Preferential or differential flotation, which is very successful on separating chalcopyrite from pyrite or pyrrhotite, but only moderately so on lead-zinc separation. (8) Flotation of copper precipitate in the form either of metal or of sulphide. (9) On native copper slimes at Lake Superior. This has been worked out experimentally and installations are planned, but not yet made. (10) Recovering values from old slime ponds in Missouri. (11) On Joplin zinc slimes from present mills and on old

[1] *Eng. Min. Jour.*, **102**, 677 (1916).

Joplin tailings dumps in connection with jigs and tables. (12) On old dumps at Midvale, Utah, followed by table separation of the froth into galena and blende products. (13) Separating chalcopyrite from nickeliferous pyrrhotite at Sudbury. (14) Experimentally on cinnabar ores. (15) On Canadian molybdenite ores.

Flotation in Gold Milling.—In gold milling there is a tendency to substitute flotation for slime concentration or cyaniding wherever there are good facilities for disposing of the flotation concentrates. The advantages are lower operating costs, better extraction, less cost of plant and the elimination of bulky slime concentrators. Just how far this will extend will be governed largely by the ability to handle the flotation concentrates by smelting or cyaniding, or in other words whether or not the ledger will show a balance in favor of flotation followed by smelting or cyaniding as compared with direct cyaniding, including in both cases not only the costs but also the losses in the process.

At Cripple Creek flotation is replacing cyanide for the low-grade ores. The Portland and Victor mills are now handling 2000 tons daily by the Callow process. The Vindicator mill has started one unit which is doing satisfactory work using mechanical agitation. In these three mills only the slimes are floated.

Following the success of the Goldfield Consolidated mill in changing from cyanide to flotation for the copper bearing gold ore, the Florence-Goldfield Co. now has an all-flotation plant for a similar ore. A good profit also is being made by the Nevada Metals Co. in working over the old dumps in this district by flotation.

The West End mill at Tonopah showed by experiment that flotation can make as good extraction as cyanide on sulphide ores, but cyanide still has the preference, since some of the ore is oxidized and since there is no satisfactory method of treating silver concentrates locally.

In the Idaho Springs district where the ores are mainly auriferous and argentiferous pyrite with some galena and blende and a little copper in siliceous gangue, the Oneida Stag and Argo mills have changed from cyaniding for the slimes to flotation. At the latter mill the two processes give about equal extraction of the gold, but flotation gives much better extraction of the silver.

In regard to the cyaniding of flotation concentrates, it is pretty well established that oil has no decomposing effect on cyanide and does not affect cyaniding.[1] One exception is reported by P. W. Avery,[2] but here the increased cyanide consumption may not have been due to the oil, but to ferrous sulphate.

[1] E. M. Hamilton, J. E. Clennell, *Min. Sci. Press*, **112**, 365, 700 (1916).
[2] *Min. Sci. Press*, **112**, 661, 813 (1916).

Filming.—The flotation of oxidized ores of lead and copper is now in actual mill use for the recovery of lead and copper carbonates. The Magma and Chino mills are perhaps the leaders in this work on copper ores. It can not be said that the process has reached its highest state of perfection in large-scale work, but it appears to be on its way.

The whole question with special reference to lead carbonates has been investigated by the U. S. Bureau of Mines at Salt Lake City.[1] The principle of operation is the formation of artificial sulphides by filming, which are then floated by oil in the regular way. The reagents tried were hydrogen sulphide both as dry gas or in solution, sulphides and sulpho compounds of sodium and also of calcium, sulphur vapor, sulphuretted oils and colloidal sulphur. Where alumina is present in considerable quantity in the ore the results from filming are poor. On lead carbonates treated dry, hydrogen sulphide gas took a long time to act, had to be used in large amounts and required the addition of sulphuric acid to get high-grade concentrates and good extraction. When a solution of hydrogen sulphide was used the results were much better. Sodium sulphide gave the best results and the amount required was 10 to 20 lb. per ton of ore in a pulp diluted to about 1 part solid to 1 of water. Further dilution was needed before flotation. Calcium sulphides were more sluggish in their action than sodium. Sulphur vapor and sulphuretted oils gave little success and colloidal sulphur did not combine at all with the ore.

On copper carbonates hydrogen sulphide was the best and when used in solution as low as ½ lb. per ton of ore gave good results. Sodium sulphide used at the rate of 2 to 3 lb. per ton also gave good results. Calcium polysulphides showed up poorly. One plant reported successful use of sulphur vapor and another plant sulphuretted oils. Colloidal sulphur did not have any action.

On zinc carbonates the filming process was not successful.

For successful filming it is apparently not necessary to form a complete sulphide coating. A particle which is only partly coated may be floated just the same as a particle of oxide which has a little sulphide on one face is lifted by the action of flotation on this sulphide face. Gahl reports that on a mixed sulphide and oxide copper ore, the addition of a little sodium sulphide after the slime sulphides have been floated off will bring up a froth which is distinctly green in color.

The filming and flotation of straight copper carbonate ore is a simple process, but in most cases the ores are combinations of sulphide and carbonate. At first sight this would seem to offer no difficulty, but unfortunately it has been found by experience that, while there is no diffi-

[1] O. C. Ralston and G. L. Allen, U. S. Bureau of Mines. *Min. Eng. World*, **45**, 137 (1916). *Eng. Min. Jour.*, **102**, 169 (1916). *Min. Sci. Press*, **113**, 171 (1916). *Met. Chem. Eng.*, **15**, 153 (1916).

culty in sulphiding the oxidized copper, the artificial sulphides have an injurious effect on the flotation of the natural sulphides with the result that in flotation the loss of natural sulphides in the tailing even exceeded the recovery of natural sulphides in the concentrates. One method of solving this difficulty would be to float the natural sulphides first and then sulphide the tailing and refloat in another machine. Another method which is giving good results in the experimental stage in Arizona consists of the use of sulphuric acid for dissolving the oxidized copper, subsequent metallizing on iron shot in a barrel and then flotation for the removal of the metallized copper together with the undissolved sulphides. Instead of iron as a precipitating agent hydrogen sulphide may be used.

J. T. Terry, Jr.,[1] ascribes this difficulty with natural and artificial sulphides to the wetting action of the soluble sulphiding reagent on natural sulphides and reports that in one plant it has been overcome.

He further points out the marked difference in the films formed on lead and copper carbonates. The former is firm, while the latter is easily scoured off. Hence the former may be attached during the grinding operation, but the latter must be attached after grinding. Further, this property makes the mechanical agitation cell unsuited to copper ores because the scouring action makes repeated filming necessary as fast as a layer is worn away, while on lead ores this type of cell is all right. The Callow cell with its gentle action is therefore proper for copper, unless the copper carbonate is reduced to colloidal slime, when of course no further scouring can take place. The presence of iron oxide in large amounts in the ore is deleterious, since much of it is filmed and floated, giving concentrates of low grade.

It has been found that cassiterite is another mineral which is susceptible to sulphide filming and flotation.

The Prince Consolidated Mining & Smelting Co. mill near Panaca, Nev.,[2] is a good example of the filming process on lead ore. This mill is treating an old oxidized tailings dump containing lead as carbonate and silver as chloride, using tables for sands and film flotation for slimes. The reagent is sodium sulphide which is thoroughly mixed with the ground pulp for 30 or 40 min. prior to passing to the Callow flotation cells. The experimental work on this ore showed assay of feed, 6.97 per cent. lead; concentrates, 38.81 per cent.; tails 1.85 per cent.; extraction of lead, 77.28 per cent.; ratio of concentration, 7.21 tons into 1.

The most information on the practical flotation of oxidized copper ores has been supplied by J. M. Callow.[3] The Magma mill in Arizona has a section for handling the various oxidized copper ores from the upper

[1] *Min. Sci. Press*, **113**, 531 (1916).
[2] W. A. Scott, *Min. Eng. World*, **45**, 946 (1916).
[3] *Bull. Am. Inst. Min. Eng.*, **122**, 245 (1917).

levels of the mine, and also for mixed oxide and sulphide tails from the main mill. The flow sheet is very simple, consisting of Hardinge mill and classifier, gas plant, and Callow cells, as shown in the figure. The hydrogen sulphide is made by heating in a retort at 300° C. California crude oil and sulphur in the proportions of 2½ lb. of oil to 1 of sulphur.

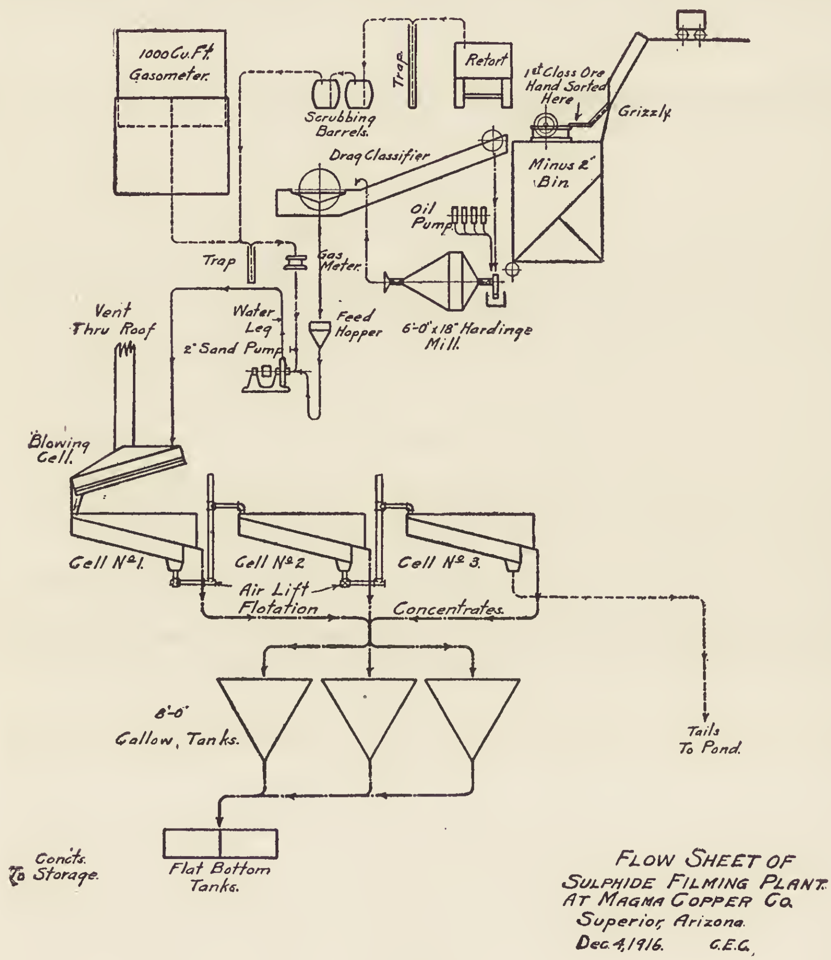

Fig. 2.

The sulphur costs 3 cts. per lb. and the oil 1 ct. The main precaution necessary is to keep out free gas, which is fatal to flotation; hence the blowing cell at the head of the first flotation cell. Gas consumption varies from ½ to 1½ lb. of sulphur per ton of sulphide tails to 3 lb. on straight carbonate ore. The average estimated cost is 8 cts. per ton of ore, or 4 cts. per ton for each pound of sulphur required. The gas is introduced into the suction of a centrifugal pump. The employment of this reagent is the result of long-continued tests against sodium sulphide, calcium sulphide and calcium sulphohydrate. The difficulty of floating natural sulphides with filmed oxides has been overcome and the opinion is now that hydrogen sulphide in proper quantity really promotes flotation of natural sulphides in company with filmed oxides, and also that it is immaterial whether the oiling is done before or after filming.

The section treats 35 tons per day. On straight oxide ores assaying from 2½ to 5 per cent. copper the latest results indicate tailings around 0.75 per cent., concentrates around 15 per cent., better than 80 per cent. extraction and a concentrating ratio of 5½ into 1. On mixed oxides and sulphides the results have been poorer, indicating that while on straight oxides the process is satisfactory, there still remains considerable work to be done on mixed ores.

Preferential Flotation.—This process in the United States, as applied to lead-zinc separations, can not be said to be entirely successful, but on the separation of chalcopyrite from pyrite or pyrrhotite as practised in Canada at the Eustis mill, and at Sudbury, or at the Calaveras mill in California and on the separation of zinc from pyrite at the Ozark mill, the work is excellent. Molybdenite is also being separated from pyrite at a small plant in Arizona.

At Broken Hill, Australia, which may be considered as the home of preferential flotation on lead-zinc ores, the Broken Hill Proprietary Co. is installing a Bradford unit where the Potter-Delprat process was formerly in use. This is a retarded float operation in which the zinc is held back by suphur dioxide gas forming calcium sulphite. Oil and air are used for floating the lead as usual, and the well-known effect of certain mineral salts (sulphates and chlorides of lime, magnesia, iron and manganese) in holding back the zinc, are to be utilized. This is perhaps the latest development at Broken Hill. The Owens, Lyster, Palmer, Horwood, old DeBavay film, and various adaptations of the Minerals Separation process are in use at different properties. At the Central mine ten Hebbard-Harvey Minerals Separation cells, with under drive and special stirrers to agitate and aerate, receive a feed containing 4.2 per cent. lead and 18 per cent. zinc. Eucalyptus oil is added to the first three cells, which yield a lead concentrate with 57 per cent. lead and a residue to the fourth cell assaying 3 per cent. lead and 18.5 per cent. zinc. Here oil and acid are added and the last seven cells remove zinc concentrate assaying 6 per cent. lead and 47 per cent. zinc and give a final tailing with 1 per cent. lead and 2 per cent. zinc.

The processes of preferential flotation may be divided into three classes: I. Roasting processes. II. Chemical Reagents. III. Control of flotation. Class I is not used in the United States. Neither is class II. Recent patents which belong in this class are Lavers patent for separation of lead and zinc by the use of chromium salts in an alkaline solution, the Higgins patent for the same separation, but using manganese salts, and the Minerals Separation patent, also for the same separation, using heated potassium dichromate of about 0.1 per cent. strength with a small amount of eucalyptus oil or creosol in a copper-lined vessel.[1] Class III is the class into which the preferential work in the United States falls. By utilizing the differences in various minerals in their ability to float, it is possible to regulate the temperature and other conditions, but more especially the amount and kind of oil, so that one mineral will be floated ahead of another. Thus in the zinc section of the Magma mill in Arizona, a mixture of No. 34 Gravity fuel oil with General Naval Stores Oil No. 17 floats zinc away from pyrite. This is only one of many similar examples.

The Calaveras Copper Co.'s mill uses 0.3 lb. per ton, Pensacola Tar & Turpentine Co. No. 400 crude wood creosote. This mill handles a heavy pyritic ore carrying chalcopyrite. The ore is crushed at the rate of 190 tons per day in a 7 by 6-ft. ball mill in closed circuit with Dorr classifier, so that 90 per cent. will pass 40-mesh, and then goes to four rougher Callow cells in parallel followed by two cleaner cells in parallel. The tailings from both the rougher and cleaner cells pass to four Callow tailings cells in parallel, which make tailings to waste and froth back to the cleaner cells. Results are shown in the table.

	Per Cent. Copper.	Per Cent. Iron.	Per Cent. Insoluble.
Feed	2.15	20.4	37.0
Concentrates	14.40	29.5	14.9
Tailing	0.09	18.0	43.4

The extraction figures out 96.4 per cent. and the ratio of concentration is 7:1. The old gravity mill concentrates assayed 5.8 per cent. copper, 35.5 per cent. iron, 37.4 per cent. sulphur, 12.7 per cent. silica and 6.5 per cent. alumina with an extraction of 50 per cent. and a concentration ratio of 6.6:1. On this class of ore gravity methods save the pyrite, but the chalcopyrite slimes more than the pyrite and goes into the tailing. By flotation the slime chalcopyrite is floated ahead of the pyrite and thus much of the pyrite is left in the tailings, which makes a richer concentrate without lowering the extraction. The cost at this mill is only 51.4 cts. per ton milled.[2]

[1] *Eng. Min. Jour.*, **101,** 22, (1916); **102,** 223 (1916).
[2] H. G. Robbins, *Min. Sci. Press*, **113,** 769, 868 (1916).

Litigation.—During 1916 the patent situation with regard to flotation has been considerably clarified. The most important decision was that handed down by the Supreme Court in Minerals Separation *vs.* Hyde in connection with the main agitation froth patent 835,120. This patent after being upheld by the District Court of Montana in 1913, held invalid by the Court of Appeals in San Francisco in 1914, was finally held valid *in part* by the Supreme Court Dec. 11, 1916.

The Supreme Court held that those claims which specified oil "amounting to a fraction of 1 per cent. on the ore" were valid while those which specified "a small quantity of oil" were invalid, Justice Clarke stating that "the patent must be confined to the results obtained by the use of oil within the proportions often described in the testimony and in the claims of the patent as 'critical proportions' 'amounting to a fraction of 1 per cent. on the ore' and therefore the decree of this court will be that the patent is valid as to claims numbered 1, 2, 3, 5, 6, 7 and 12 and that the defendant infringed these claims, but that it is invalid as to claims 9, 10 and 11. Claims numbered 4, 8 and 13 are not in issue in this proceeding."

According to this decision, the use of under 1 per cent. of oil using the *mechanical* agitation process is an infringement of the main Minerals Separation patent, but the Supreme Court was not called on to decide whether the use of under 1 per cent. oil in the *pneumatic* agitation process was an infringement.

This latter question was decided by Judge Bradford in an opinion handed down Sept. 29, 1916, in the District Court of Delaware in Minerals Separation Limited *vs.* Miami Copper Co. Judge Bradford held that the pneumatic agitation or Callow process was an infringement of patent 835,120; the fact that the agitation was more violent and different in character in the Minerals Separation process than in the Callow process and the fact that the froth is more coherent and permanent in the former than in the latter process being regarded as immaterial differences. The Court stated that:

"There is no room for doubt that agitation of the mixture in the process of the defendant is sufficiently vigorous or brisk to insure efficient ore concentration by an air flotation process such as is accomplished by the complainant by agitation under the process of the first patent in suit."

"Whether such agitation results from the stirring or beating of the mixture or the forcing or admission of air into it is immaterial; for what this court is dealing with is not an apparatus patent, but a process patent."

"Whatever may be the true explanation of the phenomenon of the continuance and disappearance of escaping bubbles, the fact remains that the defendant's process discloses a froth consisting of bubbles which have passed through modified water to the surface of the mixture, and float thereon, and with their freight of metallic particles flow over the edge of the containing vessel into a launder, thus effectively separating the valuable mineral from the gangue particles. Coherency and permanency in a froth admit of degrees, and such a degree as insures by air flotation an efficient and final separation between the metal and the gangue, whatever may be the duration of the froth, comes within the process of the first patent in suit" (*i.e.* 835,120).

The Miami case is also important for the reason that the main Minerals Separation patent No. 962,678, relating to the use of soluble frothing agents as distinguished from immiscible oils, etc., was considered by the Courts for the first time. Judge Bradford held this patent valid for all proportions of soluble frothing agents.

Interest is now centered on the decision of the Circuit Court of Appeals for the Third Circuit (hearing Jan. 27, 1917) on appeal from the decision of the District Court in Minerals Separation *vs.* Miami Copper Co.

Probably whatever way this is decided, an attempt will be made to take the case to the Supreme Court.

The Hyde decision thus ends a suit of 5 years litigation which affords another example of the unsatisfactory basis of our whole patent law procedure, and of the slow progress of litigation in general. The decision has caused considerable discussion and has not been received everywhere with satisfaction. By many it is considered not warranted by the evidence presented.

One result of the decision has been the formation of an American company called the Minerals Separation North American Corporation. The attitude of the new company appears to be more reasonable than that of the old British company; objectionable features have been eliminated from the contracts and, although royalties do not appear to have been reduced, still the representatives of the new company are doing their best to get together with their licensees and to promote cordial relations. The old figures for royalties were around 12 cts. per ton for copper ores, around 15 to 20 cts. for lead and zinc ores and 25 cts. per ounce on gold ores. Whether time will bring a reduction from these figures is a question. The main Minerals Separation patent, on which the litigation has been based, expires in 1923 and thus has 6 years more of life. The company has been under heavy expense and it is justly entitled to be allowed to pay good dividends, which it has not done up to the present. On the other hand, the tonnage already paying royalty is enormous and would undoubtedly be much further increased if royalties should be reduced so that it would be cheaper to pay them than to dodge them or fight them. Thus in the end the Minerals Separation Co. might be a gainer by the reduction.

As the situation now stands the user of flotation has the option of either using less than 1 per cent. of oil and paying royalty or using more than 1 per cent. and paying no royalty. This holds no matter whether mechanical or pneumatic flotation is used. Some companies, notably the Butte and Superior and the copper properties under the Jackling management, are using over 1 per cent. of oil with good results. The oil is probably a mixture of some cheap heavy oil, like fuel oil, with a small amount of a good frothing oil such as pine oil. The main difficulty with using over 1 per cent. of oil is, as would naturally be expected, that considerable gangue is floated, which makes a low-grade concentrate. This may be remedied in part by increasing the dilution of the pulp, which apparently has the effect of carrying off much of the excess oil, perhaps 50 per cent., into the tailings.

The whole matter comes down to the relative cost of royalty and oil. The Minerals Separation people could easily reduce their royalty so that the balance would be in their favor and then the only thing that would keep companies from signing contracts with them would be plain obstinacy. This is clearly a case where the licensor and the user can get together to their material advantage.

The litigation is by no means at an end and further efforts against the Minerals Separation Co. may be expected. The Elmore vacuum process has not yet been brought into the proceedings but that it may be a valuable weapon is evidenced by the formation of a syndicate associated with the Miami, Ray and other companies, which syndicate has acquired the American rights from Elmore.

Theory of Flotation.—Slow progress has been made in solving the laws of flotation and in spite of much research and a still larger amount of discussion of a fundamental flotation theory, we are still in about the same position as last year (see MINERAL INDUSTRY, **24**, 810), and practical operations are performed by rule of thumb. The evidence is contradictory and opinions are far from unanimous. However, the outlook for the ultimate development of a fundamental flotation theory is not hopeless. The two theories which are most favored are surface tension and the electrical theory. The latter is based on the fact that only minerals or metals that are good conductors will float. Electrified bubbles from below must be supplied to float them and a dielectric fluid is necessary to prevent dissipation of the charge. Finally, something must be added to the water to increase its conductivity.

Lack of space prevents anything but the following brief mention of the large amount of matter that has been published.

R. J. Anderson[1] has summarized the situation, reviewing the effects of surface tension and interfacial tension, adsorption, occlusion and adhesion and including phenomena of colloids, emulsions, electrolytes and electrostatic charges. He favors surface tension, rejects occlusion, but admits that electrostatics may be a small contributing factor.

T. A. Rickard[2] attributes flotation to the physical phenomena of surface tension and adhesion.

A. F. Taggart and F. E. Beach,[3] have submitted various experimental data and worked out a theory involving surface tension and contact angles, adsorption, adhesion and viscosity. Electrical forces are not given an important rôle except possibly as attaching and holding sulphides to the bubble films.

G. W. Van Ardsdale[4] explains flotation as a phenomenon involving surface tensions, interfacial tensions, contact angles and surface films. Electric charges play a part only as they affect these; oils with frothing qualities likewise affect these. Emulsification of oil is harmful and acid is of benefit in that it prevents emulsification.

W. D. Bancroft[5] lays particular stress on the property of adsorption in explaining flotation.

D. H. Norris[6] considers the action of gravity, temperature and surface tension. He should be credited with not being satisfied with the term surface tension, as he has undertaken to analyze this property of matter and bring it down to terms of molecular cohesion.

W. H. Coghill[7] attributes flotation to surface tension and explains the latter on the basis of molecular forces. Critical temperatures, adhesion and cohesion also play a part. A surface-tension film is retained on sulphides when immersed in water. This film encloses small air bubbles. These are inflated by gases expelled from the solution; and finally a large air bubble impinges against, and coalesces with, the attached bubbles and the mineral is carried to the surface by the resulting bubble which is inflated with air and expelled gas.

Further, Coghill[8] brings out the forces existing in surface films and their effect on adsorption and coalescence. Viscosity is another important factor that must be considered along with variable surface tension and coalescence.

[1] *Bull. Am. Inst. Min. Eng.*, **115**, 1119 (1916); **120**, 2234 (1916). *Min. Sci. Press*, **113**, 47 (1916). *Met. Chem. Eng.*, **15**, 82 (1916).
[2] *Can. Min. Inst.*, **19**, 5 (1916). *Min. Sci. Press*, **112**, 333, 407, 469, 930 (1916).
[3] *Bull. Am. Inst. Min. Eng.*, **116**, 1373 (1916); **120**, 2232 (1916). *Met. Chem. Eng.*, **15**, 518 (1916).
[4] *Met. Chem. Eng.*, **14**, 572 (1916). *Eng. Min. Jour.*, **101**, 851 (1916).
[5] *Met. Chem. Eng.*, **14**, 631 (1916).
[6] *Min. Sci. Press*, **112**, 232 (1916).
[7] *Min. Sci. Press*, **113**, 341 (1916).
[8] *Min. Sci. Press*, **112**, 314 (1916); *Colo. School of Mines Mag.*, **6**, 59 (1916).

J. H. Hildebrand[1] bases flotation on the principle of surface tension involving liquid-gas contacts (foams), liquid-liquid (emulsions) and liquid-solid (suspensions) and the effects of various liquid solvents on these contacts. In the case of suspensions a further factor has to be considered, viz., the electric charges on the suspended particles due to adsorbed ions.

H. H. Smith[2] considers that surface tension, adhesion and adsorption explain flotation. The formation of the right kind of minute bubbles depends upon the presence of a proper contaminating agent, of which oil happens to be the one in common use. The attachment of bubbles to sulphide particles can not be effected by either surface tension or adhesion, but is probably accomplished by the phenomenon of "hysteresis" of the contact angle. The stability of the bubble, once formed, requires that the force of adhesion of the liquid to solid be reduced relatively to the force of surface tension and this is brought about by allowing the solid to take on a film of gas by adsorption or a film of oil or other greasy matter by adhesion. Stability of the bubble after rising to the surface is the result of the forces of surface tension and adsorption under the action of small amounts of contaminating agents.

H. J. Stander[3] attributes the flotation property of sulphides to the difficulty of wetting them. On the other hand, the gangue minerals are considered to be more porous, absorb water, are wetted and sink. Going further[4] he favors the theory of static charges as far as matter in colloidal form is concerned, but supplements this with the theory that the varying action of acid and of different oils, especially soluble or non-soluble oils, is of great importance in their effect on the relative surface tension or interfacial tension of oils and water, and on the adhesion between oil and air particles. Other substances may be substituted for oil and flotation of sulphides obtained.

F. G. Fuchs[5] has experimentally shown that when ore particles are wet with water, oil adheres to sulphides and not to gangue.

G. Huston and J. A. Block[6] explain flotation as due to buoyancy accompanied by electric attraction and they eliminate surface tension as an active factor. All particles are oiled, but gangue particles give up the oil and sulphides annex air, following the laws of attraction and repulsion of static charges.

F. A. Fahrenwald[7] discredits the electric theory of flotation and undertakes to show by results of experiments that the electric forces are not sufficient to account for the force necessary to float particles.

[1] *Min. Sci. Press*, **113**, 168 (1916).
[2] *Min. Sci. Press*, **113**, 16 (1916).
[3] *Am. Min. Congress*, **19**, 510 (1916); *Min. Eng. World*, **45**, 910 (1916).
[4] *Eng. Min. Jour.*, **101**, 576 (1916); *Min. Eng. World*, **45**, 317 (1916).
[5] *Met. Chem. Eng.*, **14**, 484 (1916).
[6] *Min. Sci. Press*, **112**, 6, 115, 849 (1916).
[7] *Min. Sci. Press*, **112**, 375 (1916).

C. T. Durell[1] defends his theory that the requirements for flotation are "nascent gases" in solution and "occluded gases" in the particles. These two gases meet and increase until a bubble is formed large enough to float the ore particle. The mineral particles which are floatable are claimed to contain the most occluded gases. Oil is not essential to the theory, but it lends stability to the froth. Electrolytes act to produce osmotic pressure, which expels the occluded gases.

O. C. Ralston[2] admits the truth of Durell's statement that nascent gas only forms into bubbles when it has nuclei on which to form, but proves experimentally that gas does not need to be nascent in order to attach itself to sulphides. Doubt is also expressed on the statements that minerals with the most occluded gases are the most easily floated and that the effect of electrolytes is to expel the occluded gas and that the action of oil is to increase the surface tension and increase the stability of the froth. Ralston believes that a comprehensive theory of flotation will have to take into consideration many different physical properties of small particles, including electrical charges and interfacial tensions.

H. A. Megraw[3] touches upon the action of oil in flotation and gives it two functions: (1) to decrease surface tension and make a more durable froth; (2) to attach itself to the sulphides so that they will not become wetted.

G. Belchic and R. O. Neal[4] have measured the surface tensions of oil-water emulsions and find that large quantities of oil added to water (acid, alkaline and neutral) do not necessarily produce a marked reduction in the surface tension of water and in some cases with acid or alkaline water the oil increases the surface tension. The foaming property of the oil does not appear to be entirely dependent on surface tension and a working theory of flotation therefore must include other factors beside surface tension.

D. Cole,[5] reasoning from what occurs in the flocculation of slimes during settling is inclined toward the electric theory of bubble flotation.

Apparatus.—The flotation machines which do nearly all the work in the United States are the Minerals Separation, Janney and the Kraut-Kohlberg, all using mechanical agitation and the Callow, Inspiration and Cole-Bergman, all using the pneumatic agitation.

The Minerals Separation machine is preferred at Anaconda, while in Arizona the Callow and Inspiration are more used. The results obtainable by the two types are not greatly different. The Callow uses

[1] *Min. Sci. Press*, **112**, 264, 273 (1916); *Colo. School of Mines Mag.*, **6**, 27 (1916); *Mex. Min. Jour.*, **21**, 207 (1916); *Met. Chem. Eng.*, **14**, 251 (1916); *Can. Min. Jour.*, **37**, 121 (1916).
[2] *Min. Sci. Press*, **112**, 621 (1916).
[3] *Eng. Min. Jour.*, **102**, 50 (1916).
[4] *Min. Eng. World*, **45**, 487 (1916).
[5] *Min. Sci. Press*, **112**, 79 (1916).

less power and possibly a little less oil, but the froth is not as persistent. The claim that the Callow machine is more sensitive is disputed by its inventor.

For a detailed description of the Inspiration and the Cole-Bergman machines the reader is referred to the papers by Messrs. Cole and Gahl.[1] The latter machine lost out to the Callow in tests by the Arizona Copper Co., the latter being simpler and yielding better recovery of metal with lower operating costs and less power consumption.

The Kraut-Kohlberg machine is a comparatively new machine and is used by the Phelps Dodge Co. in the Burro Mountain mill and elsewhere. It is also being tried out in Missouri with promising results. As shown in the figure, it consists of a long hollow cylindrical drum mounted on a horizontal shaft. The drum is provided with a series of longitudinal air slots and a larger number of longitudinal riffles running the entire length of the drum. The drum revolves rapidly inside a close-fitting casing. The froth is produced by the action of the riffles coupled with the action of air drawn in through the slots by centrifugal force. This froth passes into the spitzkasten. Feed is introduced at the bottom through a side pipe as shown and in practice these cells may be connected in series for repeated treatment. The tailings issue from the bottom of the spitzkasten.

A launder type of flotation machine is described by B. M. Snyder[2] and an improved Callow type by J. M. Hyde.[3]

The Wyman air jet cell is in use at the Standard mill at Silverton, B. C.[4]

The Florence Goldfield mill is reported to be trying the Jones Belmont flotation machine, but no description is given.[5]

A new principle is introduced in the Hauks Emulser, or Vogelsang Ore Emulser, which makes use of a steam or air jet for emulsifying the oil and water with the ore. This is a very compact device which is reported to be in use by some of the companies which employ over 1 per cent. of oil.

For description of machines used in testing, with full details of methods of carrying on the tests, the reader is referred to an article by O. C. Ralston and G. L. Allen.[6]

Oils and Reagents.—While the properties of oils are pretty well known, still their application to flotation can be determined only by experiment. Anyone who is engaged in testing ores by flotation knows that although

[1] *Bull. Am. Inst. Min. Eng.*, **117**, 1611, 1627 (1916).
[2] *Eng. Min. Jour.*, **102**, 1060 (1916).
[3] *Min. Sci. Press*, **113**, 199 (1916).
[4] J. B. Parmelee, *Min. Eng. World*, **44**, 1121 (1916); *Min. Mag.*, **15**, 110 (1916).
[5] H. B. Clapp, *Min. Sci. Press*, **113**, 628 (1916).
[6] *Min. Sci. Press*, **112**, 8, 44 (1916).

certain oils will in general yield certain results, still it is impossible to predict just what oils will yield the best results. It is common now to use oil mixtures to save the expense of a single high-priced oil and the problem is further complicated by the fact that the properties of a mixed oil are not always the mean properties of its ingredients. The millman who is running a mill day after day soon formulates rules as to the effect of different oils on his particular ore. Similarly, an ore tester will develop some more general rules. When once the problem has been solved for a given ore it is usually found that considerable variation in oils may be made without harm. In other words, it may almost be said that many oils are applicable to an ore provided the proper conditions are worked out for their application.

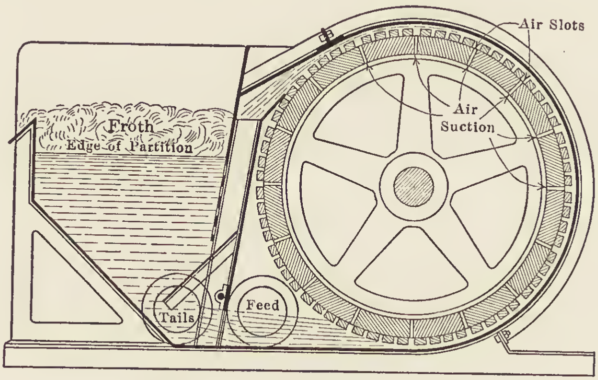

Fig. 3.—K and K flotation machine.

An interesting example of the vagaries of flotation reagents is reported by J. A. Pearce[1] in the Argo mill at Idaho Springs, where months of trial yielded only unsatisfactory results in spite of all the variations that a study of the theory and practice of flotation could suggest. Finally the process began to work satisfactorily and has done so ever since, and it has been impossible to find any reason for the sudden improvement.

Other instances might be given of where some little factor has made the difference between success and failure, such as the solving of the problem of floating chalcocite by adding the oil during grinding, the beneficial action of finely divided iron at Inspiration and a case where laboratory tests on an ore gave good results which were not obtainable when a mill was erected, the reason being that the water used in the laboratory contained salts while the mill water was very pure. The solution was, of course, to add salts to the mill water.

The use of salts to aid flotation does not seem to have received the attention in the practical way that it merits, copper sulphate being about

[1] *Met. Chem. Eng.*, **14**, 706 (1916); *Min. Sci. Press*, **113**, 427 (1916).

the only salt that is used. Most of the plants are able to get results in a so-called neutral circuit, that is they add no acid or alkali but this does not mean that there may not be small amounts of dissolved salts in the water which have an important and unsuspected action. The Anaconda company using kerosene acid sludge as one of the ingredients of its oil mixture necessarily has an acid circuit and adds sulphuric acid to make it more so. On the other hand, the porphyry copper mills find that alkali is necessary, or at least desirable for good results. On a galena ore experiments have shown that a small amount of soap acts beneficially when used with a proper oil.[1]

Of the many oils used the general division into frothers and collectors is universally recognized, the former roughly including the wood products and the latter the mineral oils and tars. Thick oils form a viscous coherent froth. Pine oil forms a voluminous froth with small brittle bubbles. Being a soluble oil an economy is effected in the use of this oil by returning the clarified water after flotation. This is not the case with insoluble oils. Creosol, creosotes and turpentine in general form a tougher and more elastic froth than pine oil. Coal tars are poor frothers but form large tough bubbles. Light oils, as gasoline and naphtha, are used for thinning down heavy wood and coal tars. An excess of oil increases the weight of the concentrates with but little addition to the extraction. Highly diluted pulps do not froth as well with the same amount of oil as do denser pulps. Tests at the Missouri School of Mines show that oils with the highest dielectric constants give the best results as a rule.[2] The greater the dilution of the pulp the cleaner are the concentrates; also the amount of froth for an ore depends on the dilution of the pulp rather than on the mineral content, an ore with say 5 per cent. mineral needing as much oil as an ore with 25 per cent. mineral.

For further details of the properties of flotation oils and results of tests the reader is referred to papers by Mueller;[3] Megraw;[4] Clayton and Peterson;[5] C. H. Wright;[6] Palmer, Allen and Ralston;[7] Whitaker, Belchic, Neal and Van Velzer.[8]

A list of dealers in flotation oils has been given by O. C. Ralston,[9] also a table of the annual consumption of the various kinds of oil. He quotes prices of 5 cts. per gal. or less for coal tar, 15 to 30 cts. for coal creosote and wood creosote and 45 to 60 cts. or more for pine oils.

[1] M. H. Thronberry, *Min. Sci. Press*, **112**, 715 (1916).
[2] C. Y. Clayton, *Met. Chem. Eng.*, **15**, 504 (1916).
[3] *Eng. Min. Jour.*, **102**, 31 (1916).
[4] *Eng. Min. Jour.*, **102**, 50 (1916).
[5] *Mo. School of Mines Bull.*, Aug., 1916. *Eng. Min. Jour.*, **102**, 825 (1916). *Min. Sci. Press*, **112**, 598 (1916).
[6] *Colo. School of Mines Quart.*, **11**, No. 2, 1 (1916).
[7] *Bull. Am. Inst. Min. Eng.*, **116**, 1387 (1916). *Eng. Min. Jour.*, **102**,311 (1916).
[8] *Met. Chem. Eng.*, **15**, 131 (1916).
[9] *Min. Sci. Press*, **112**, 869 (1916). *Met. Chem. Eng.*, **14**, 712 (1916). *Min. Eng. World*, **44**, 1079 (1916).

Attention has been turned to the possibilities of sage brush as a source of flotation oil. It is reported to take less oil and give better extraction than pine oil. Allowing $1 as the cost of gathering 1 ton of brush and $5 for distillation, and a yield of 4 per cent. the cost is 60 cts. per gal. which compares favorably with pine oil which is reported to be selling at 67 cts. per gal. in the West. The above estimate of the cost of sage brush oil is very rough and may be reduced by utilization of by-products.[1,2]

Disposal of Flotation Concentrates.—A knowledge of the general character and fineness of flotation concentrates is necessary in order to understand the problem of their recovery and disposal. The froth from a Southeast Missouri lead mill when sized and assayed gave the results shown in the table.[3]

SIZING TESTS OF FROTH

Mesh.	Weight, Per Cent.	Per Cent. Lead.	Per Cent. of Total.	
			Lead.	Gangue.
−65+80	0.00	0.00	0.00	0.00
−80+100	0.63	41.40	0.52	0.79
−100+115	0.00	0.00	0.00	0.00
−115+150	0.47	33.40	0.32	0.95
−150+170	0.53	31.60	0.34	0.89
−170+200	0.00	0.00	0.00	0.00
−200+260	0.78	46.80	0.72	0.86
−260 (*a*)	10.92	62.40	13.50	7.30
−260 (*b*)	86.67	49.30	84.60	89.20

(*a*) −260-mesh product which settled in 5 min. after stirring. (*b*) −260-mesh product which did not settle in 5 min. after stirring.

Note that the bulk of the froth is finer than 260-mesh and will not settle in 5 min.; also that this product is low-grade and contains the greater part of the gangue. The use of an electrolyte is suggested by Fred Walsh[4] to avoid the trouble which is sometimes found with colloidal gangue matter.

The recovery of flotation concentrates involves two operations, viz.: the breaking down of the froth and the elimination of water. A spray of water is practically universal for the first operation although reagents like acid or lime have been found to assist the work. A patent on an atomizing jet for this purpose has been issued, the main object being to avoid the addition of excess of water which has to be later eliminated.[5] Froth from pneumatic cells, being much lighter and more persistent than froth from mechanical agitation cells, is more easily broken down.

[1] G. H. Clevenger, *Bull. Am. Inst. Min. Eng.*, **117**, 1685 (1916); **119**, 1897 (1916). *Eng. Min. Jour.*, **102**, 420 (1916). *Min. Sci. Press*, **113**, 806 (1916).
[2] M. Adams, *Bull. Am. Inst. Min. Eng.*, **117**, 1683 (1916). *Min. Eng. World*, **45**, 490 (1916). *Min. Sci. Press*, **113**, 467 (1916).
[3] C. Y. Clayton, *Mo. School of Mines Bull.*, Aug., 1916. *Eng. Min. Jour.*, **102**, 867 (1916).
[4] *Met. Chem. Eng.*, **14**, 399 (1916).
[5] *Min. Eng. World*, **44**, 951 (1916).

For the second operation, the elimination of water, the standard practice is the Dorr thickener followed by the Oliver or Portland filter, although instances exist of the use of ordinary settling tanks and steam-drying of the settled pulp. Occasionally screw dewatering devices come into the operations.

The Dorr thickener has already been referred to under Classifying and Settling. When used on copper sulphide froth an average of 40 sq. ft. of settling area are required per ton of concentrates per 24 hr., although sometimes considerably less and sometimes over 50 sq. ft., depending on the colloidal character of the ore treated and on the quantity and quality of the oils used. For zinc and lead froth 12 to 15 sq. ft. per ton per 24 hr. are sufficient. Where it is found that the capacity has been over-estimated in designing the plant it is possible to rectify the error by placing Dorr trays in the tanks since for this work a shallow tank is efficient. Two tanks operating in parallel do more efficient work than in series.

In general froth from the cells carries considerably over 50 per cent. moisture. The water added to break down the froth raises this to 60 or 70 per cent. and in some cases up to 90 per cent. The thickener reduces this to about 40 per cent. moisture on copper sulphides, about 35 per cent. on lead and to between 30 and 40 per cent. on zinc. Where the thickening capacity is too low, causing an overflow which is not clear, the tendency of froth to remain on top of the surface of the water is increased. The froth will build up until it flows over the baffles and into the overflow. To avoid this trouble and also trouble with a too dilute underflow, Callow recommends that the thickeners be run intermittently instead of continuously. Dorr takes exceptions to this and claims that the continuous system is best and that the proper remedy is to increase the thickener capacity.

Filtering has been the cause of much worry, largely on account of feeding pulp which is too dilute. The feed should not contain more than 50 per cent. moisture and the lower the moisture content the better. The variations in filter capacity range from 6 to 23 sq. ft. of filtering area per ton of dry solids in 24 hr. Where the table concentrates are mixed with the flotation concentrates before thickening, the filtering process is much helped since the filter does not require so high a vacuum and delivers a larger tonnage of dry concentrates than when handling —65-mesh slimes alone. At Inspiration the practice is to send the mixed table and flotation concentrates to a drag classifier which delivers coarse material direct to the filters and fine to Dorr thickeners and thence to the filters.

The cake from an Oliver filter will contain between 10 and 15 per cent.

moisture and further elimination of water must be done by drying. It is not advisable to go below 5 or 6 per cent. moisture where loss by dusting begins. The Lowden drier made by the Colorado Iron Works is finding application in some mills for this work.

In other mills where drying is practiced, somewhat similar apparatus making use of the same principle of raking the cake over a fire, or steam-heated surface, are in use. Sometimes the cake as it leaves the filter is delivered over a steam-heated plate.

The practice in southeast Missouri lead mills which formerly used steam-heated tanks exclusively for settling and drying is now changed and Dorr tanks are the custom. The change to Oliver filters has not proceeded so far, although they are gaining, and some mills still dry the Dorr product in steam tanks. On these galena concentrates the moisture content of the filter cake cannot be reduced much below 13 or 14 per cent. and steam-drying is necessary to reduce this to 7 per cent. for shipment to the smelter.

Washing of flotation concentrates with water to remove some of the fine gangue is reported to be in use in Australia but is not practiced in the United States.[1]

Details of Practice.—It is impossible to cover in this article all of the details of progress in flotation and for further information the reader is referred to the Bibliography both of Flotation and of Mills, especially to the articles by Laist and Wiggin[2] on Flotation at Anaconda, by Gahl[3] on the History of Flotation at Inspiration, by Burch[4] on the Inspiration Mill, by Cole[5] on flotation in the Clifton-Morenci District of Arizona, and by Callow[6] on Flotation in 1916.

The U. S. Bureau of Mines has issued a Bibliography of Flotation and plans to keep this work up to date by future issues. The importance of the Flotation process is evidenced by the fair size of the present publication.

Four recent books on flotation are from the pens of T. A. Rickard, H. J. Stander, H. A. Megraw and T. A. Rickard with O. C. Ralston. These with Hoover's pioneer book on the subject represent all the books on this subject to date.

Accessory Apparatus

Conveyors and Elevators.—Belt conveyors and belt and bucket elevators are the common devices for transporting and lifting ore and pulp

[1] R. J. Anderson, Handling flotation concentrates; *Met. Chem. Eng.*, **14,** 381 (1916): *Min. Eng. World*, **45,** 57 (1916): *Mex. Min. Jour.*, **21,** 212 (1916).

[2] *Bull. Am. Inst. Min. Eng.*, **111**, 549 (1916); **119,** 1889 (1916). *Min. Mag.*, **14,** 227, 228 (1916). *Can. Min. Inst.*, **19,** 67 (1916). *Min. Sci. Press*, **112,** 446; **113,** 847 (1916). *Met. Chem. Eng.*, **14,** 328 (1916). *Eng. Min. Jour.*, **101,** 469, 480, 508, 562 (1916). *Min. Eng. World*, **44,** 471 (1916). *Can. Min. Jour.*, **37,** 113 (1916).

[3] *Bull. Am. Inst. Min. Eng.*, **117,** 1627 (1916); **118,** 1870 (1916); **119,** 1879 (1916). *Min. Sci. Press*, **113,** 460, 495 (1916). *Met. Chem. Eng.*, **15,** 393, 455 (1916).

[4] *Bull. Am. Inst. Min. Eng.*, **117,** 1467 (1916). *Eng. Min. Jour.*, **102,** 411, 457 (1916).

[5] *Bull. Am. Inst. Min. Eng.*, **117,** 1611 (1916). *Min. Mag.*, **15,** 355 (1916). *Eng. Min. Jour.*, **102,** 712 (1916). *Min. Sci. Press*, **113,** 549, 556, 633 (1916).

[6] *Bull. Am. Inst. Min. Eng.*, **122,** 245 (1917).

in a mill. These adjuncts do not always receive the same consideration as the flow sheet and the concentrating machines, and it is therefore a pleasure to note that two articles have appeared which supply the millman with valuable information on this necessary apparatus. A. O. Gates' article[1] is devoted to the installation and operation of belt elevators considering the strength of parts, critical speeds, feeding methods, etc. The article by A. Robertson and A. M. Johnston[2] covers much the same ground for conveyor belts as well as including methods and results of testing rubber and balata belts.

Frenier Pump.—In the new Nevada-Packard mill the characteristic tendency of the Frenier pump to slop over at intervals is entirely overcome by using a by-pass to return a little of the discharge pulp. The height of lift of this pump is increased from its rated 20 to 23 ft. by introducing a little compressed air into the upright discharge pipe. This gives the extra lift since the air acts on the principle of the Pohle air lift.

Mill Principles, Theory and General Ideas

A very complete list of new mill construction and changes in 1916 has been compiled.[3] In studying this one can not help but note how flotation is the main cause of the changes which are chiefly along the line of simplification of flow sheets, and how many small simple mills have been put up to use this process. Just one example will serve to show this general trend. In the case of the Miami mill the predicted simplification of flow sheets by the use of flotation has come to pass since in the future all the ore is to be crushed to flotation size and floated without intermediate steps. This mill has operated a 125-ton test plant on this basis for a year.

An investigation has been made by J. J. Beringer[4] on the physical condition of cassiterite in Cornish mill products. From measurements of size by the microscope and by settling in water and also from specific gravity determinations, some very interesting figures have been obtained on the sizes of cassiterite going into the tailings of fine concentrating machines.

The simplification of flow sheets means simpler mill buildings, fewer floors and less mill height and leads to a revision of ideas on mill sites. The subject of selecting the site with reference to these points has been discussed by E. S. Wiard.[5]

[1] *Eng. Min. Jour.*, **102**, 40 (1916).
[2] *So. Afr. Inst. Eng.*, March, 1916. *Coll. Guard.*, **111**, 749 (1916). *Met. Chem. Eng.* **15**, 262 (1916). *Min. Sci. Press*, **113**, 209 (1916). *Eng. Min. Jour.*, **102**, 9 (1916).
[3] *Min. Eng. World*, **46**, 1 (1917).
[4] *Inst. Min. Met.*, **24**, 407 (1916).
[5] *Eng. Min. Jour.*, **102**, 1 (1916).

The latest word in mill construction is the new Nevada-Packard mill.[1] This has a gravity flow on a site that originally sloped 15°. All foundations are of concrete. To handle 1000 tons daily the main building is 64 by 144 ft., the tube mill addition 40 by 42 ft. and the crushing plant 24 by 32 ft. In all 220,000 feet B.M. of lumber was used. The frame is of Oregon pine and the sides and roof of fir covered with asbestos roofing which makes an excellent non-conductor of heat and cold. Useless timber was eliminated by carefully calculating stresses and the mill is very open. Butt joints and corbel join stringers instead of the usual more expensive splice joint. The latter is used in the trusses. Thickener and agitator mechanisms and transmission machinery are suspended from the trusses. Good clearances exist around all machines and tanks and runways are built around all the mechanical appliances. Belts and transmission parts are overhead and well guarded. The total cost was $65,451.94 divided as follows: Equipment (machinery, supplies, etc.) $38,765.34; grading (materials, labor and teams) $4213.05; concrete (material and labor) $1738.48; framing (material and labor) $10,096.57; construction (material and labor) $9093.50; engineering $1545.00. Labor cost $4 and $5 per shift.

Examples of Practice

The Alaska Juneau mill which is expected to treat between 8000 and 12,000 tons daily is the latest development in the treatment of the low-grade Alaska gold ores similar to those of the Alaska-Treadwell and Alaska-Gastineau mills. These ores carry auriferous pyrite and a little galena in a siliceous gangue. This new mill solves the problem by straight concentration using fine-crushing in ball mills and table concentration. It consists of a coarse-crushing department in two units, a concentrating department in twelve units and a retreatment department in one unit.

Coarse-crushing Complete

1. Two revolving tipples each handling four cars. To (2).
2. Coarse ore bin, 2000 tons. By four 60-in. belt feeders to (3).
3. Four 8 by 5-ft. grizzlies with 8-in. spaces. Oversize to (4); undersize to (5).
4. Two 36 by 48-in. jaw-breakers crushing to 6 in. To (5).
5. Four 4 by 8-ft. grizzlies with 3-in. spaces. Oversize to (6); undersize to (7).
6. Four No. 9 Gates breakers crushing to 3 in. To (7).
7. Four 30-in. belt conveyors followed by four distributing boxes and two 36-in. shuttle conveyors. To (8).
8. Mill ore bin, 8000 tons. To (9).

[1] H. G. Thomson, *Min. Sci. Press*, **113**, 377 (1916).

Concentrating Department. One Unit Described

9. Two 30-in. belt feeders. To (10).
10. One 8 by 6-ft. ball mill. To (11).
11. One trommel, 12-mesh. Oversize to (16); undersize to (12).
12. One V-tank. Spigot to (13); overflow to (18).
13. Mechanical distributor. To (14).
14. Four Deister roughing tables. Lead concentrates to (24); iron concentrates to (27); tailings to (15).
15. Two three-spigot classifiers. Spigots to (16); overflows to (18).
16. From (11) and (15). One shovel-wheel unwaterer, 44 by 8 in. Sands to (17); slimes to (18).
17. One 6 by 12-ft. tube mill. To (18).
18. From (12) (15) (16) (17). Two settling tanks. Spigots to (19); overflow to waste.
19. Two mechanical distributors. To (20).
20. Eight Deister finishing tables. Lead concentrates to (22); iron concentrates to (26); middlings to (21); tailings to waste.
21. Two Wilfley tables. Lead-iron concentrates to (26); tailings to waste.

Re-treatment Department, Complete

22. Seven lead concentrates receptacles. Settling to (23); overflow to (26).
23. One lead concentrates storage hopper. To (24).
24. From (14) (23). One shovel-wheel unwaterer, 18 by 2 in. Sands to (25); slimes to (29).
25. One Deister laboratory table. Free gold concentrates; lead concentrates to smelter; tails to (29).
26. From (20) (21) (22). Two 5½-in. belt elevators. To (27).
27. From (14) (26) (31). Two shovel-wheel unwaterers, 44 by 8 in. Sands to (28); slimes to (29)
28. One 5 by 5-ft. ball pebble mill. To (29).
29. From (24) (25) (28). Sump. By two 4-in. centrifugal pumps to (30).
30. One four-spigot classifier. Spigots to (31); overflow to (32).
31. Four Deister finishing tables. Iron concentrates to smelter; middlings to (27); tailings to waste.
32. Settling tanks. Solids to waste (?); overflow to waste.

The Arizona Copper Co. has worked out their flow sheet in preparing for the flotation department so as to save the coarser particles on Butchart tables. The flotation feed goes to (1).

1. Grinding mills. To (2).
2. Primary drag classifiers. Sands to (3); slimes to (5).
3. Secondary drag classifiers. Sands to (4); slimes to (5).
4. Wilfley tables with Butchart riffles. Concentrates to smelter; tailings to (1).
5. Flotation cells.

The advantages of this scheme are twofold: the coarse mineral is saved without sliming; the table concentrates when mixed with the flotation concentrates make a better feed for the filter than flotation concentrates alone.

The new Britannia copper mill in British Columbia[1] has four sections, each treating about 630 tons in 24 hr. The ore is crushed to 3½ in. at the mine. At the mill the ore is screened at 1.5 in. and shipping ore picked out from the oversize. The residue is crushed in a jaw-breaker and joining the undersize is further crushed by rolls using a ¼-in. limiting trommel. Over 1.5 mm. is jigged in Hancock jigs and under 1.5 mm. goes to Overstrom tables. Jig tailings are crushed in rolls. The dewatered table tailings join this roll product and go to tube mills operating in closed circuit with hydraulic classifiers, and thence to Minerals Separation flotation cells. These cells also receive the sediment from Dorr thickeners which receive the overflow of the table tailings dewaterer.

The ore contains chalcopyrite and about twice as much pyrite, besides a little zinc blende and galena. Average analysis of mill feed is 2.74 per cent. copper, 7.95 per cent. iron, 1.5 per cent. zinc, 6 per cent. sulphur and 71.25 per cent. silica. The products are as follows:

	Per Cent. of Total.	Copper Content, Per Cent.
Picked ore	10	10 to 18
Jig concentrate	25	16 to 17
Table concentrate	25	14 to 15
Flotation concentrate	40	14 to 15

The feed to the flotation cells contains 1.9 per cent. copper and the flotation tailing 0.12 per cent. copper. The concentrates average 26.8 per cent. iron and 20.8 per cent. silica. This shows a little selective action in floating the chalcopyrite away from the pyrite.

The mill extraction averages 95 per cent. and the cost of milling is 50 cts. per ton which will be reduced to 30 cts. when the mill is running smoothly.

In the conservative Joplin zinc district of Missouri which is understood to include the outlying districts even to Miami, Oklahoma, the investigation of the U. S. Bureau of Mines[2] is bearing fruit. This investigation showed that the average mill extraction is around 65 per cent. The losses occur: (1) in jig middlings as included grains, (2) in jig tailings as fine free mineral and (3) in table tailings as slime mineral. The suggestion for (1) is re-grinding, for (2) the removal of slimes before jigging since the present system of dewatering jig tailings is not very efficient and fine values go to waste with the coarse tails; for (3) improved classification before the tables and the introduction of flotation for the slimes.

On the rich Miami ores tailings run as high as 5 to 7 per cent. zinc

[1] T. A. Rickard, *Min. Sci. Press,* **113,** 693 (1916).
[2] C. A. Wright, *U. S. Bur. Mines Bull.; Min. Sci. Press,* **113,** 357 (1916).

by the old process. The recovery of values from old tailings piles is illustrated by the Granby mill at Chitwood where the material is screened at 1.25 mm., and the oversize jigged. Jig middlings are crushed in rolls to 1.25 mm. and join the screen undersize going to the classifier and tables. The Granby mill at Granby has followed the Bureau of Mines recommendation and uses a 1.25-mm. screen for dewatering ahead of the jigs and also does systematic table work.[1]

Dorr thickeners for collecting slimes are in common use and flotation additions are being made. In the Miami district three mills already have flotation, one using mechanical agitation cells and two using pneumatic cells. A froth assaying 61 per cent. zinc is obtained by using a mixture of Naval Stores Oil No. 18 and wood creosote with nitre cake.

The two latest and most modern mills in the Miami field have separate crushing plants, automatic samplers, cleaner tables for the general concentrate, flotation and all modern improvements.

In the lead mills of southeast Missouri the line of progress is in simplification and finer grinding. The new Federal mill, treating 2500 tons daily is built on a side-hill site. Crushing is done in two Symons gyratory-breakers followed by four Symons fine-reduction crushers set at 10 mm. The mill follows the general practice of the district in Hancock jigs, Butchart tables and flotation for slimes. Marathon and Hardinge mills are being tried for grinding jig middlings.

The mills of this district have always made a small amount of lead-iron-zinc middlings which in the course of time have accumulated to large amounts. The recovery of lead from this product is a problem but moderate success is met by grinding in small Hardinge mills and tabling.

The Bunker Hill and Sullivan mill in Idaho has been described by R. S. Handy,[2] including details of the flotation operation and milling costs. No radical changes have been made in the flow sheet.

The treatment of lead-zinc ores in the Slocan district, B. C.,[3] is represented in the Van Roi and Standard mills which follow the regular coarse-crushing, screening, jigging, classifying and table practice. On this class of ores finer-crushing is a positive disadvantage. Callow screens are being introduced in the place of classifiers to avoid pulp dilution.

Washing of Minnesota low-grade sandy iron ores carrying free silica is steadily increasing. At the new washer of the Rowe mine[4] at Riverton, the ore is crushed to 6 in. in a 36 by 48-in. jaw-breaker and screened in a trommel with 6-in. holes. The oversize is hand-picked for waste yield-

[1] L. L. Wittich, *Eng. Min. Jour.*, **101**, 557 (1916).
[2] *Eng. Min. Jour.*, **102**, 35 (1916).
[3] D. Lay, *Eng. Min. Jour.*, **101**, 463 (1916).
[4] *Min. Eng. World*, **44**, 517 (1916).

ing clean ore and the undersize goes to a 25-ft. log washer delivering ore at the upper end and water and fine material at the lower end. The latter is re-treated in two 18-ft. turbo log washers, which yield a fine-ore product and tailings which are settled in a settling tank the spigot of which goes to five double-deck Overstrom tables, where a further recovery of fine ore is made.

At Nashwauk, Wis.,[1] there are several iron-ore washing plants all of which, with the exception of the La Rue, follow in principle the process just described but differ somewhat in details. The La Rue mine substitutes for the turbos and tables a device called the Wetherbee concentrator which is really a form of annular classifier employing centrifugal force as well as a rising current of water.

Treatment of Coal

For details of progress the reader is referred to the bibliography. The following notes cover very briefly the most important features.

Shaking screens find more application in coal than other types. The operation and care of these screens have been discussed by J. A. Garcia,[2] including pointers on how to avoid difficulties from faulty design or improper operation. W. H. McGann[3] goes into details of the mounting and driving, including screens with suspending rods, screens with supporting rods and screens running on rollers. C. C. Wright[4] has considered the details of design and adjustment and arrives at the conclusion that there is no way of exactly calculating the best slope, speed, length of stroke and area, but these figures must be obtained by experiment on different coals.

Settling and Draining. Removal of Mud.—Even in coal, Dorr thickeners are found, the Stag Canon Fuel Co. at Dawson, N. M., having two of them for clarifying the water after coal washing. The first is 30 ft. in diameter and receives the fine coal and overflows the colloids to the second 50 ft. in diameter where the colloids are settled out and clean water returned for re-use. The fine coal settling in the first thickener is elevated by perforated bucket elevator and discharged to an automatic centrifugal drier.

For removing mud, due to fire-clay, in washing fine coal a special shaker screen with water spray is satisfactory, or if it is inadvisable to use the amount of water required by this apparatus, the same result may be obtained by washing the coal on a Massco (modified Wilfley) table.[5]

[1] L. A. Rossman, *Eng. Min. Jour.*, **102,** 491 (1916).
[2] *Coal Age*, **9,** 669 (1916).
[3] *Coal Age*, **9,** 368 (1916).
[4] *Coal Age*, **9,** 284 (1916).
[5] W. L. Smith, *Coal Age*, **9,** 647, 766 (1916).

General.—Economies in Coal Washing have been discussed by S. Hunter,[1] dealing particularly with arrangements for mechanical, handling, draining, etc., to avoid labor.

Anthracite.—In the preparation of anthracite the new Underwood breaker of the Pennsylvania Coal Co. near Scranton, represents the latest and most efficient practice. This is a concrete breaker up to the tops of the ore pockets and steel covered with corrugated iron above this level.[2]

The Loomis breaker at Nanticoke, with a capacity of 7500 tons of coal per day, is the largest and in many respects is an ideal plant.[3]

The operation and adjustment of anthracite jigs have been discussed by E. E. Finn,[4] and results of tests on power consumption by the machines used in anthracite breakers have been given by H. M. Warren, A. S. Biesecker and E. J. Powell.[5]

Bituminous.—In the washing of bituminous coal the newest plant in the Birmingham district is that at the Flat Top mine. This handles 1600 tons daily, using five primary jigs and one re-washing jig.[6]

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[2] C. M. Young, *Coal Age*, **9,** 4 (1916).
[3] C. M. Young, *Coal Age*, **9,** 413 (1916).
[4] *Coal Age*, **9,** 622 (1916).
[5] *Bull. Am. Inst. Min. Eng.*, **110,** 181 (1916); **113,** 901 (1916).
[6] J. G. Hamlin, *Coal Age*, **10,** 841 (1916).

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DATA OF THE WORLD'S PRINCIPAL MINES

By S. F. Shaw

Compiled from Annual Reports of the Respective Companies

Name of Mine.	Situation.	Year.	Tons.	Profits.	Dividends.	Reserves, Tons.	Cost Per Ton.
Abosso Gold	W. Af.	'15–'16	113,300	£25,023	£29,000		6.56
Ahmeek	U. S.	1916	1,164,010	3,449,710	2,800,000		2.39
Alaska Gold Mines	Alaska	1916	1,892,788	451,026			0.96
Alaska Juneau	Alaska	1916					
		1916	180,113				
Alaska Mexican	Alaska	1915	216,428	99,477	90,000	1,188,866	
Alaska Treadwell	Alaska	1915	900,211	718,521	650,000	6,611,571	
Allouez	U. S.	1916	566,960	1,524,511	900,000		1.96
Amalgamated Zinc	Aus.	½–1915	161,043	£168,028	£75,000		
		½–1915	156,196				
Anaconda Copper	U. S.	1916	5,589,157				
Antelope Gold Mine	Rhod.	1915	47,858	£19,876		110,157	8.47
Arizona Commercial	U. S.	1915	44,353	211,774			5.83
Arizona Copper	U. S.	'15–'16	905,486	£988,225	£328,510		4.55
Ashanti Goldfields	Rhod.	'14–'15	138,316	770,000	720,000	433,900	10.00
Associated Northern Blocks	Aus.	'15–'16	30,778	£5,363			8.27
Associated Gold Mines	Aus.	'15–'16	116,165	£1,963			5.54
Atlas Min. & Mill. Co.		'15–'16	36,647	17,265*		12,000	5.38
Aurora Con	Tran.	1915	138,399	—22,377		414,000	3.22
Aurora West	Tran.	1915	172,491	£14,796		550,444	5.48
Balaghat Gold	India	1915	36,684	£285		26,133	9.00
Baltic	U. S.	1915	378,443	949,965			
Basset Mines	B. I.	1915	32,524	—£3,023			7.89
Bantjes	Tran.	1915	235,400	£9,421 *		142,800	5.22
Beaver Con	Ont.	'15–'16	30,093		120,000		
Blackwater	N. Z.	1915	54,643	£24,439	£24,999	91,251	8.19
Braden Copper	Chile.	1915		2,476,294			
Brakpan	Tran.	1915	725,568	£290,005	£300,000	3,017,000	4.91
Briseis Tin	Tas.	1914	595,000†	£4,266		7,400,000	
British Broken Hill	Aus.	1915		£13,000			
British Columbia Copper	B. C.	1915		—24,918		9,075,000	
Broken Hill North	Aus.	½–1916	70,200	£131,552	£120,000		
Broken Hill Block 10		1916	34,914	£13,853	£5,000		
Broken Hill Block 14	Aus.	½–1915	4,339	£4,358			
		½–1915	2,875	£10,874	£6500		
Broken Hill Proprietary	Aus.	½–1915	115,374	£196,227	£118,100		
		2/2–1915	114,579	£282,970	£118,10		
		½–1916	66,423		£118,100		
Broken Hill South	Aus.	½–1916	92,553		£120,000		8.08
		2/2–1916	157,059	£255,789	£120,000	3,500,000	6.09
Brunswick Con. Gold	U. S.	1916	34,091				5.90
Buena Tierra	Mex.	1915	16,993	£5,308		281,500	7.14
Buffalo	Ont.	'15–'16	37,152	231,344		18,000	7.17
Bullfinch Prop.	Aus.	1915	76,886	£16,313	£23,807	97,334	5.19
Bunker Hill (Ariz.)	U. S.	1915	10,746				
Bunker Hill & Sullivan	U. S.	1915	455,205	145,854	1,062,750	3,573,930	6.66
Burro Mountain	U. S.	1915				2,550,000	
Butte & Superior	U. S.	1916	627,370	8,873,446		1,044,850	4.50*
Caledonia	U. S.	1915	42,628	761,797			11.38
Calumet & Arizona	U. S.	1915		11,155,005			11.16
Calumet & Hecla	U. S.	1916	3,166,274				2.62
Cam & Motor	Trans.	'15–'16	157,028	£8,561		577,281	6.28
Camp Bird	U. S.	'15–'16	25,601	£78,436	£45,473		
Canadian Mining Corp.	Ont.	1915	127,126	1,284,140	518,750	36,246	10.15
Cape Copper	S. W. Af.	'14–'15	83,143	£22,371	£5,400	510,990	
Carn Brea & Tincroft	B. I.	½–1915	29,693	—£24			5.17
		2/2–1915	29,795	£1,290			5.64
		½–1916	28,586	£3,691			6.24
Centennial	U. S.	1916	150,617	265,750			1.92
Central Chile Copper	Chile	1915	28,602	—£32,612			
Cerro Gordo		1916	12,789				
Champion	U. S.	1915		3,709,049	3,100,000		2.29
Champion Reef	India	'15–'16	194,311	£106,163	£104,000	375,991	9.80
Chiksan Mining Co.	Chosen	1916	65,932	272,074	70,000	117,000	4.94
Chief Con	U. S.	1916	83,606		176,481		
Chino Copper Co.	U. S.	1916	3,094,400	12,509,161	7,177,335	95 ,55 5,843	2.00

Note:—Abbreviations used in table; Aus., Australia; B. C., British Columbia; B. I., British Isles (Cornwall); Hond., Honduras; Malay, Federated Malay States; N. Z., New Zealand; Ont., Ontario, Canada; Rhod., Rhodesia; S. Af., South Africa; S. W. Af., Southwest Africa; Tas., Tasmania; Tran., Transvaal; W. Af., West Africa.

—Loss for the year. * Working profit or cost. ½ First half. 2/2 Second half. †Cubic yards. § Pesos. ††Dump.

All profits and dividends are in dollars except where otherwise noted.

Name of Mine.	Situation.	Year.	Tons.	Profits.	Dividends.	Reserves, Tons.	Cost per Ton.
City & Suburban	Tran.	1915	337,023	£249,880	£187,000	637,400	5.15
City Deep	Tran.	1915	677,200	£485,615	£421,875	2,733,600	5.89
Coniagas	Ont.	1915	55,437	....	740,000	....	.....
Cons. Arizona Smelting	U. S.	1915	90,531	....	....	300,000	.....
Cons. Goldfields of N. Z.	N. Z.	1915	25,844	£18,045*	....	36,836	4.49
Cons. Interstate-Callahan	U. S.	'15–'16	120,684	3,100,491	3,254,930	....	.....
Cons. Langlaagte	Tran.	1915	636,300	£138,572	£237,500	2,248,656	5.20
Cons. Main Reef	Tran.	'15–'16	342,895	£162,931*	£115,545	856,740	4.78*
Cons. Mining & Smelting	B. C.	'15–'16	444,017	996,496	776,338	....	.....
Copper Queen	U. S.	1915	830,777	....	....	14,330,421	.....
Copper Range	U. S.	1915	1,651,870	3,564,762	1,182,003	....	1.31
Cordoba Copper	Spain	1916	84,800	£21,450	£20,000	142,914	10.42
Crown Mines	Tran.	1915	2,501,450	£846,405	£611,068	9,938,000	4.70
Crown Reserve	Ont.	1915	....	133,307	106,128	....	.....
Daly Judge	U. S.	1915	69,744	500,700	300,000	....	12.05
Dolcoath	B. I.	½–1916	41,384	£4,376	....	....	6.86
		⅔–1916	37,963	—£4,167	....	....	7.30
Dolores	Mex.	1915	....	....	....	126,663	.....
Dome	Ont.	'15–'16	347,640	912,380	600,000	2,600,000	2.56
Ducktown Sulphur and Copper	U. S.	1915	150,400	£41,382	£27,472	3,530,000	.....
Durban Roodepoort	Tran.	1915	170,831	£34,890	£31,250	326,526	3.83
Durban-Roodepoort Deep	Tran.	1915	320,830	£52,051*	£33,000	977,700	5.65*
East Butte	U. S.	1915	150,911	782,988	....	....	.....
East Rand Proprietary	Tran.	1915	1,962,816	£636,277*	£275,163	4,800,000	4.58*
Eileen Alannah	Rhod.	1915	45,978	£33,198	....	186,130	6.75
Eldorado Banket	Rhod.	'15–'16	48,880	£61,999*	£45,000	52,978	6.54
Elkton Con	U. S.	1915	36,103	32,968	100,000	....	.....
Elm Orlu	U. S.	'15–'16	206,752	495,757	....	....	.....
El Paso	U. S.	1915	34,442	37,443	....	19,000	.....
Esperanza	Spain	1916	108,761	£51,029	£35,000	738,000	.....
Falcon Mines	Rhod.	'15–'16	218,792	£195,688	....	862,066	7.43
Federal Mining & Smelting	U. S.	1915	437,686	310,367	479,443	1,107,600	6.45
Ferriera	Tran.	'15–'16	644,960	£458,694*	£379,750	1,632,600	5.08
Frisco (Federal)	U. S.	1915	58,113	....	....	....	.....
Frontino & Bolivia	Bol.	'15–'16	25,484	£24,458	£16,339	42,200	14.10
Gaika Gold	Rhod.	'15–'16	37,795	£32,367	£34,187	89,591	7.48
Geduld Prop	Tran.	1915	303,900	£119,326	£97,000	2,100,000	5.60
Geldenhuis Deep	Tran.	1915	639,800	£128,600*	£117,150	1,826,800	5.21*
Giant Mines of Rhod.	Rhod.	'14–'15	57,086	£1,298	....	113,982	3.73
Ginsberg	Tran.	1915	185,764	£42,847*	£31,500	278,118	4.29
Glencairn Main Reef	Tran.	1915	251,940	£21,716*	£27,500	117,430	2.73
Globe & Phoenix	Rhod.	1915	412,073	£157,233	£80,000	189,200	.....
Glynn's Lydenberg	....	'15–'16	49,104	£36,531*	£27,625	78,282	5.39
Golden Horseshoe	Aus.	1915	243,564	....	£82,500	704,359	.....
Goldfield Con	U. S.	1916	338,680	428,620	....	....	5.26
Gold Hunter	U. S.	1915	118,764	31,662	....	....	4.91
Golden Kopje Prop	Rhod.	'15–'16	131,567	—£10,694	....	157,675	4.87
Granby Cons	B. C.	'15–'16	1,897,251	....	....	23,000,000	.....
Great Boulder Perseveranee	Aus.	1915	239,314	£3,201	....	544,474	5.00
Great Boulder Prop	Aus.	1915	195,524	£289,479	£262,500	494,564	7.30
Great Fingall	Aus.	1915	43,706	£9,136	....	31,010	8.97
Grenville	B. I.	1916	22,207	—£9,919	....	....	7.46
Greenhill-Cleveland	U. S.	1915	28,125	497,864	....	....	.....
Hampton-Conclurry	Aus.	½15–16	50,693	£143,816	£70,000	299,000	21.54
Hecla	U. S.	1915	123,986	561,752	565,000	100,000	3.84
Hedley Gold	B. C.	1915	74,265	374,746	300,000	423,522	5.68
Hollinger	Ont.	1915	334,750	....	1,560,000	1,600,800	3.98
Homestake	U. S.	1915	1,573,822	2,345,545	2,210,208	....	2.66
Hornsilver	U. S.	1916	....	....	40,000	....	.....
Huelva Sulphur & Cop	Spain	'14–'15	53,247	£5,440	....	....	7.66
Inspiration	U. S.	1916	5,353,880	20,629,489	8,548,050	91,789,120	1.76
Iron Blossom	U. S.	1915	....	....	300,000	....	.....
International Nickel	Ont.	1915	....	....	5,288,693	....	.....
Isle Royale	U. S.	1916	....	1,396,655	750,000	....	.....
Ivanhoe	Aus.	1915	238,512	£106,233	£105,000	1,026,801	5.63
Jibutil Gold Mines	India	'15–'16	35,700	....	....	24,300	.....
Jim Butter Tonopah	U. S.	'15–'16	52,142	....	343,604	19,158	10.80
Jumbo Extension	U. S.	'14–'15	16,420	339,373	125,317	86,750	18.97
		'15–'16	35,541	408,358	465,000	....	15.82
Jumbo Gold	Tran.	'14–'15	26,150	£7,744	....	....	.....

Name of Mine.	Situation.	Year.	Tons.	Profits.	Dividends.	Reserves, Tons.	Cost per Ton.
Jupiter	Tran.	1915	79,600	...	...	952,000	4.94
Kerr Lake	Ont.	'14–'15	23,035	550,775	620,000	54,830	...
		'15–'16	58,850	...	...	...	8.03
Kinta Tin Mine	...	'15–'16	915,000	£22,421	£19,800	...	2.09
Knights Central	Tran.	1915	326,385	£45,433*	...	406,400	4.49*
Knights Deep	Tran.	'15–'16	1,307,300	£197,940	£111,528	2,614,000	2.96*
Kyshtim Corp.	...	1915	361,750	...	...	2,535,000	...
Lake Copper	U. S.	'15–'16	59,848	87,018	...	...	4.12
Lake View & Star	Aus.	'15–'16	195,732	£12,992	£30,000	293,527	5.00
Langlaagte Estate	Tran.	1916	595,507	£148,898*	£44,325	1,315,813	4.43*
La Rose	Ont.	1915	54,405	230,662	299,725	10,000	4.63
La Salle	U. S.	1916	144,829	78,856	...	...	2.00
Last Chance	U. S.	1915	136,180	47,370	...	...	4.21
Le Roi No. 2	B.C.	'15–'16	18,958	£13,616*	£6,000	...	7.20
Lena Goldfields	Siberia	'14–'15	974,234†	...	...	2,238,850†	...
Lonely Reef	Rhod.	1915	56,910	£37,250	£35,230	157,279	10.05
Luipaardsolei	Tran.	'15–'16	256,005	£39,117	£23,600	826,138	4.67
Magma	U. S.	1916	93,808	...	...	125,000	...
Main Reef West	Tran.	'15–'16	307,680	£42,661*	...	386,960	4.70*
Mammoth	U. S.	1915	240,473	...	...	...	...
Mary Murphy	U. S.	1915	60,500	281,196	...	...	5.56
Mason & Barry	Portugal	1915	192,942	...	£55,551	...	...
Mass Copper	U. S.	1915	323,335	167,473	...	...	2.12
May Con.	Tran.	1915	168,320	£10,030*	£14,437	...	3.40*
May Day	U. S.	1915	...	...	96,000	...	...
McIntyre Porcupine	Ont.	'15–'16	105,758	327,524	...	201,920	4.28
McKinley-Darragh-Savage	Ont.	1916	62,676	282,304	269,723	...	5.00
Messina Development	S. Af.	'15–'16	111,909	£268,721*	£136,337	151,409	...
Mexico Mines of El Oro	Mex.	'15–'16	...	...	...	503,300	...
Meyer & Charleton	Tran.	1915	176,400	...	£260,000	485,246	6.92*
Miami Copper	U. S.	1916	1,842,017	7,984,133	4,295,905	50,400,000	2.93
Mines Co. of America	Mex.	1915	...	48,546	...	...	...
Moctezuma	Mex.	1915	424,027	...	...	2,912,830	...
Modderfontein B.	Tran.	1915	510,700	£530,945	£472,500	2,790,000	4.78
Modderfontein Deep	Tran.	1915	390,150	£212,726	£175,000	2,670,000	5.72
Mohawk	U. S.	1914	649,649	432,053	100,000	...	1.47
		1915	829,789	1,511,575	600,000	...	1.43
Montana Tonopah	U. S.	'14–'15	63,754	...	...	...	...
Morning (Federal M. & S.)	U. S.	1915	250,260	571,560	...	...	5.50
Mount Bischoff	Tas.	½–1915	52,187	£2,793	...	1,720,000	...
Mount Boppy	Aus.	1915	79,526	£18,823	£10,550	215,956	6.16
Mount Lyell	Tas.	½–1916	166,497	£242,962	...	2,809,656	...
		½–1916	166,637	£110,559	...	3,430,200	...
Mt. Morgan	Aus.	'14–'15	200,034	£168,642	£150,000	2,722,756	...
Mysore	India	1916	305,845	£266,642	£289,750	1,000,000	9.09
Namaqua Copper	Cap. Col.	1915	27,859	£39,083	£37,732	66,731	...
Nevada Con. Cop.	U. S.	1916	3,922,634	15,435,359	...	67,933,117	2.35
Nevada Wonder	U. S.	'15–'16	...	282,528	211,251	...	...
New Chuquitambo	Peru	'14–'15	19,556	£2,200	£2,240	...	2.68
New Goch	Tran.	1915	363,200	£95,125	£55,000	668,600	3.40
New Heriot	Tran.	1915	155,900	£109,881*	£86,250	536,680	5.27
New Idria	U. S.	1916	...	419,235	400,000	...	...
New Kleinfontein	Tran.	1915	636,150	£137,420	£115,154	2,866,941	5.31
New Modderfontein	Tran.	'14–'15	611,800	£590,487	£437,500	5,179,000	8.19
		'15–'16	635,300	£500,060	£455,000	7,477,390	6.25
New Primrose	Tran.	1915	259,300	£69,097*	£56,875	265,623	3.02*
New Unified	Tran.	1915	161,940	£58,016*	£50,000	399,140	3.18
New York & Honduras Rosario	Hond.	1915	117,790	236,142	240,000	343,716	16.89§
Nigel	Tran.	1915	135,100	£14,545*	£11,155	...	6.26*
Nipissing	Ont.	1915	78,657	1,441,428	1,200,000	182,748	10.02
North Anantapur	...	'15–'16	32,390	£10,223*	£7,531	44,000	6.91*
North Butte	U. S.	1915	378,105	1,127,646	387,000	...	8.01
North Moccasin	U. S. ...	1915	47,038	...	...	...	...
North Star	U. S. ...	1916	111,330	352,294	300,000	...	6.26*
Nourse	Tran.	'15–'16	663,490	£101,261	£82,782	2,169,300	4.98
Nundydroog	India	1916	111,330	352,294	300,000	...	6.26*
		1916	98,000	£105,731	£99,050	217,300	11.65
Old Dominion	U. S.	1916	152,059	3,532,125	...	...	...
Ooregum	India	1915	153,266	£121,411	£120,231	367,625	7.75
Oriental Con.	Chosen	'14–'15	297,889	660,096	858,780	746,790	3.23
		'15–'16	309,730	667,820	644,080	...	2.91

Name of Mine.	Situation.	Year.	Tons.	Profits.	Dividends.	Reserves, Tons.	Cost per Ton.
Oroyo-Links	Aus.	1915	141,300	£365	....	158,622	5.07
Osceola	U. S.	1916	....	2,776,160	1,826,850	....	......
Ouro Preto	Brazil....	1915	85,400	£9,545	£1,221	74,705	6.10*
Pahang Consol	Malay	'15–'16	162,200	£98,924	£68,155	....	......
Phelps-Dodge	U.S.-Mex.	1916	2,305,072	24,030,904	14,625,000	....	......
Pigg's Peak, Dev.	....	'15–'16	23,590	—£12,685	....	18,261	6.64
Pittsburg Dolores	....	'15–'16	27,269	....	....	....	7.67
Plymouth Con	U. S.	1915	129,500	188,000	173,000	....	3.00
Poderosa	Chile	1915	....	£17,025	....	138,000	......
Porcupine Vipond	Ont.	1915	35,899	196,919	....	90,000	5.47
Porcupine Crown	Ont.	1915	41,326	297,853	240,000	....	7.68
Portland	U. S.	1915	426,586	798,460	260,000	....	......
Prestea Block A	S. Af.	1915	280,138	£16,622	....	634,264	6.95
Princess Estate	Tran.	1915	268,500	£846	....	....	6.12
Progress Mines	N. Z.	1915	36,160	—£901	....	80,000	6.15
Quincy	U. S.	1915	1,269,000	1,873,674	880,000	....	......
Randfontein Central	Tran.	1916	2,209,622	£402,575*	....	4,944,302	4.39*
Ray Con	U. S.	1916	3,363,466	12,084,166	4,337,955	93,373,226	2.29
Regende	Rhod.	1915	121,500	£20,527	£13,324	363,684	3.58
Rena Copper Mines	Spain	1915	122,120	£42,641	£27,955	....	......
Right of Way	Ont.	1915	....	3,392	8,428	....	......
Rio Tinto	Spain	1915	....	£1,129,821	£1,112,500	....	......
Robinson Gold	Tran.	1915	688,800	£380,293	£385,000	565,100	4.10
Robinson Deep	Tran.	'14–'15	585,730	£277,217	£225,000	1,513,000	4.41
Roodepoort United	Tran.	1915	408,086	£21,113*	....	720,309	4.21
Rooiberg Minerals	Tran.	'14–'15	26,333	£29,924	£22,500	14,714	10.36*
		'15–'16	28,133	£22,994	£18,000	....	16.28
Rose Deep	Tran.	1915	789,700	£278,303*	£227,500	3,605,390	4.11*
San Miguel Copper	....	1915	26,834	—£1,835	....	....	......
Santa Gertrudis	Mex.	'15–'16	227,616	....	360,000	1,214,000	6.65
Selukwe	Rhod.	'14–'15	17,125	£2,056	£9,350	26,106	......
Seoul Mining	Chosen	1915	83,560	....	....	1,221,331	3.94
Seven Troughs Coalition	U. S.	1915	....	172,874	180,381	....	......
Shamva	Rhod.	1915	576,640	£199,197*	£165,000	1,750,730	2.02
Shannon	U. S.	1915	....	209,678	....	....	......
Shattuck-Arizona	U. S.	1915	102,391	1,174,028	875,000	....	......
Sheba Gold	Tran.	'15–'16	83,125	£11,610	....	40,500	6.16
Silver King Con	U. S.	'16–'17	....	....	294,562	....	......
Simmer & Jack Prop.	Trans.	'15–'16	797,900	£303,792*	£262,500	1,935,000	3.50*
Simmer Deep	Tran.	1915	769,100	£34,841	....	1,585,000	3.74
Sons of Gwalia	Aus.	1915	163,379	£51,726	£41,437	....	6.01
South Crofty	B. I.	1916	71,706	£16,703	£16,250	....	5.84
South Eureka	U. S.	'15–'16	145,124	125,924	125,354	....	3.09
South Klagurli	Aus.	'15–'16	117,190	£16,335	£12,500	157,617	5.43
Spassky Copper	Siberia	1914	20,697	£115,502	£97,894	524,400	......
Standard (Federal)	U. S.	1915	52,958	39,291	....	....	5.54
Standard Silver-Lead	B. C.	1915	39,447	510,430	250,000	....	5.44
St. John del Rey	Brazil	½–1916	94,300	£72,240	£25,485	....	8.20
		'15–'16	192,500	£182,497*	£66,377	788,439	6.94*
St. Joseph Lead	U. S.	1915	2,127,333	4,283,425	854,980	....	......
Sub-Nigel	Trans.	'15–'16	91,130	£32,759*	£32,368	214,000	7.90*
Success	U. S.	1915	21,867	898,931	....	....	16.32
Sudan Goldfields	S. Af.	1916	26,297	£15,194	£6,587	60,193	7.08
Sulphide Corp.	Aus.	'15–'16	184,470	£771,308	£305,000	1,858,200	......
		½–1915	126,785	....	....	....	......
Superior Copper	U. S.	1916	185,315	331,933	100,000	....	2.40
Tamarack	U. S.	1915	217,027	78,988	....	....	3.06
Tanalyk Corp.	Russia	1915	33,445	....	....	201,200	......
Taquah	W. Af.	'15–'16	68,012	£64,425	£77,495	209,299	9.85
Tekka	Malay	'15–'16	432,700†	£21,712	£21,000	....	0.16
Temiskaming	Ont.	1915	26,927	96,585	75,000	....	......
Tennessee Copper	U. S.	1915	511,940	1,242,693	600,000	5,087,421	2.83
Tharsis Sulphur and Copper	Spain	1916	403,408	213,412	....	....	......
Tincroft	B. I.	¾–1916	29,095	—£1,190	....	....	6.45
Tolima Mining	Colombia	'15–'16	6,310	....	....	....	......
Tomboy	U. S.	'14–'15	145,857	396,223	226,000	535,000	4.49
Tomboy	U. S.	'15–'16	156,488	£76,923	....	....	4.92
Tom Reed	U. S.	'15–'16	29,916	....	163,720	11,000	......
Tongkah Harbor	Malay	'15–'16	3,363,750	£40,808	£60,000	....	0.09
Tonopah Belmont	U. S.	'14–'15	181,424	1,456,698	1,462,504	226,921	6.88
		'15–'16	165,157	1,001,028	750,016	142,164	6.85*
Tonopah Extension	U. S.	'14–'15	91,882	596,891	283,026	12,651	9.40
		'15–'16	91,981	....	....	....	10.97
Tonopah Mining	U. S.	1916	80,532	....	1,000,000	102,056	8.51
				....	150,000	72,100	8.71

Name of Mine.	Situation.	Year.	Tons.	Profits.	Dividends.	Reserves, Tons.	Cost per Ton.
Trimountain	U. S.	1915	349,684	654,747	....	....	2.26
Tronoh	Malay	1915	....	£29,311	£16,000	....	......
United Copper	U. S.	1916	....	123,706	....	....	......
United Globe Mines	U. S.	1916	206,163	....	....	....	......
United States S. R. & M. Co.	U.S.-Mex.	1915	1,066,025	6,592,324	1,965,561	....	......
United Verde Ext.	U. S.	1916	80,159	6,938,100	1,050,000	1,000,000	37.96
Utah Con	U. S.	1916	434,576	1,924,176	1,250,000	203,400	......
Utah Copper	U. S.	1916	11,012,026	33,747,740	19,493,880	369,845,558	1.90
Van Ryn	Tran.	1915	462,850	£235,697*	£225,000	1,973,000	3.62*
Van Ryn Deep	Tran.	'15–'16	460,310	£210,236*	£175,000	1,950,191	3.65
Victoria	U. S.	1915	133,984	....	....	....	1.85
Village Deep	Trans.	1916	156,700	....	....	....	......
Village Main Reef	Tran.	1915	301,610	£137,666	£94,400	635,050	5.76
Viloro Syndicate	U. S.	1915	715,918†	4,483	£4,288	....	0.087
Vindicator	U. S.	1915	218,487	1,350,164	225,000	2,000,000††	......
Waihi	N. Z.	1915	192,333	£155,409	£99,181	806,052	4.87
Waihi Grand Jc.	N. Z.	1915	125,800	£46,344	£38,439	136,400	6.04
Wallaroo & Moonta	Aus.	1916	167,507	231,504	140,000	....	......
Wanderer	Rhod.	'15–'16	146,257	£3,161	....	44,000	1.93
West Rand Con	Tran.	1915	369,400	£98,108	....	1,838,380	4.61
Wilbert Mining	U. S.	'15–'16	15,204	....	30,000	....	3.56*
Winona	U. S.	1915	102,594	....	....	....	2.02
Witwatersrand Deep	Tran.	1915	519,292	£213,839*	£158,125	1,673,000	4.15*
Witwatersrand Gold	Tran.	1915	504,800	£274,251*	£234,812	1,480,423	3.56*
Wolhuter	Tran.	'15–'16	424,500	£161,123*	£129,000	1,302,160	4.25
Yellow Pine	U. S.	1916	22,662	....	....	....	9.92
Yukon Gold	Alaska	1915	12,817,804†	2,121,031	1,050,000	....	......
Zinc Corp	Aus.	1915	154,628	£115,529	£94,079	1,504,211	......

AUSTRALASIA

In the following tables the production of minerals and metals in each of the Australian states and New Zealand is separately itemized. In the tables relating to foreign commerce, however, the states are not separately treated, the combined statistics of the Commonwealth now being officially reported. Figures in full-faced type are either provisional figures or estimates.

MINERAL PRODUCTION OF NEW SOUTH WALES (*a*)
(In metric tons or dollars; £1 = $5) (*b*)

Year.	Alunite.	Antimony and Ore.	Bismuth Ore.	Chrome Ore.	Coal.	Coke.	Cobalt Ore.	Copper Ore.
1902.....	3,702	58	10	508	6,037,083	128,902	35	3,190
1903.....	2,524	13	23	1,982	6,456,523	163,161	155	1,750
1904.....	376	111	41	404	6,116,126	173,742	6	2,470
1905.....	2,745	394	56	53	6,738,252	165,568	*Nil.*	487
1906.....	1,886	2,490	25	15	7,748,384	189,038	*Nil.*	(*g*)
1907.....	2,021	1,780	17	30	8,796,451	258,683	*Nil.*	(*g*)
1908.....	1,099	119	9	*Nil.*	9,293,377	288,413	*Nil.*	(*g*)
1909.....	3,556	97	9	*Nil.*	7,132,548	207,553	*Nil.*	(*g*)
1910.....	1,154	99	7	*Nil.*	8,304,693	286,854	10	(*g*)
1911.....	1,023	168	9	*Nil.*	8,831,175	268,935	*Nil.*	(*g*)
1912.....	3,479	64	6	*Nil.*	10,044,487	245,050	*Nil.*	(*g*)
1913.....	2,269	18	9	*Nil.*	10,587,734	303,585	*Nil.*	(*g*)
1914.....	3,089	37	15	*Nil.*	10,557,911	309,677	*Nil.*	(*g*)
1915.....	1,443	646	18	*Nil.*	9,601,137	424,479	*Nil.*	(*g*)
1916.....	330	630	30	*Nil.*	1,145,308	444,632	*Nil.*	(*g*)

Year.	Copper Matte, Ingot, and Regulus.	Diamonds. *Carats.*	Gold. (*b*)	Lead, Argentiferous. (*f*)		Lead, Pig. (*f*)	Molybdenite.	Opal.
				Ore.	Metal. (*e*)			
1902....	5,560	11,995	$3,333,064	371,496	15,660	(*d*)4,685	16	$700,000
1903....	8,094	12,239	5,255,421	335,870	18,779	(*d*)3,561	31	500,000
1904....	6,654	14,296	5,576,966	373,362	30,212	(*d*)5,977	26	285,000
1905....	7,899	6,354	5,669,099	420,266	28,244	214	20	295,000
1906....	9,911	2,827	5,249,762	377,890	22,573	60	34	282,500
1907....	10,260	2,539	5,112,852	441,024	20,687	20,084	22	395,000
1908....	9,215	2,205	4,646,451	364,488	(*h*)	15,174	9	209,000
1909....	7,078	5,474	4,231,211	273,628	(*h*)	15,724	29	309,000
1910....	13,096	3,606	4,011,055	322,780	(*h*)	21,534	50	331,000
1911....	12,295	5,771	3,743,672	343,902	(*h*)	17,552	21	286,500
1912....	11,211	2,239	3,416,560	350,850	(*h*)	17,528	57	170,349
1913....	9,619	5,573	3,093,331	397,783	(*h*)	23,947	80	143,513
1914....	6.713	1,580	2,573,496	342,411	(*h*)	26.405	62	132,670
1915....	7,085	839	2,738,677	287.329	(*h*)	30,793	33	32,015
1916....	6,270	1,901	2,235,357	253,872	(*h*)	25,876	55	106,365

Year.	Platinum. *Kg.*	Oil Shale.	Silver. *Kg.*	Tin.		Tungsten Ore.	Zinc. (*c*) (*f*)
				Ore.	Block.		
1902......	11.6	63,886	33,195	23	502	....	1,281
1903......	16.5	35,332	34,195	556	949	9	21,086
1904......	16.6	38,477	34,880	586	1,084	106	58,523
1905......	12.4	38,838	12,987	726	817	228	105,189
1906......	6.4	32,965	8,865	(*h*)	1,698	245	105,325
1907......	8.6	48,088	63,573	(*h*)	1,945	409	241,015
1908......	4.2	47,044	77,490	(*h*)	1,822	247	281,147
1909......	13.7	49,500	53,430	(*h*)	1,974	129	379,907
1910......	10.3	69,385	55,176	(*h*)	1,898	168	476,125
1911......	14.6	76,306	54,975	(*h*)	1,960	288	524,666
1912......	19.0	87,399	74,314	(*h*)	2,107	231	528,872
1913......	13.7	17,268	68,267	(*h*)	3,071	172	515,105
1914......	7.6	50,880	89,318	(*h*)	2,355	200	365,059
1915......	1.7	15,723	100,698	(*h*)	2,223	84	193,988
1916......	2.6	17,706	87,139	(*h*)	2,163	268	213,118

(*a*) From the Annual Report of the Department of Mines, New South Wales. (*b*) Where gold is reported, £1 = $4.866. (*c*) Spelter and concentrate. (*d*) Includes minor quantities of lead carbonate and chloride, the product of the leaching plant at Broken Hill. (*e*) Includes a small quantity of silver-sulphide. (*f*) Exported. In the case of lead, 101,811 long tons was produced in 1912 from N. S. Wales in Australia; see article on lead. (*g*) Included with metal. (*h*) Included with ore.

MINERAL PRODUCTION OF QUEENSLAND (*a*)

(In metric tons or dollars; £1 = $5)

Year.	Bismuth Ore.	Coal.	Copper.	Gold. (*b*)	Lead.	Manganese Ore.
1902......	1	509,579	3,845	$13,238,500	271	4,674
1903......	11	515,950	4,995	13,818,653	3,856	1,341
1904......	20	520,232	4,440	13,210,869	2,079	843
1905......	15	537,795	7,337	12,249,157	2,464	1,541
1906......	7	610,480	10,238	11,257,316	2,854	1,131
1907......	6	694,204	12,959	9,641,789	5,240	1,134
1908......	22	707,473	14,932	9,613,051	7,207	1,403
1909......	11	768,720	14,727	9,416,576	5,323	613
1910......	22	885,108	16,649	9,123,531	2,435	805
1911......	10	905,568	20,709	7,981,791	1,799	1,167
1912......	(*c*) 201	917,202	23,505	7,191,846	3,179	313
1913.....	(*c*) 185	1,045,243	24,050	5,492,585	3,663	27
1914......	(*c*) 197	1,071,237	18,738	5,156,919	736	6
1915......	(*c*) 253	1,041,003	89,318	5,303,515	494	203
1916......	(*c*) 142	922,341	19,833	4,569,755	625	653

Year.	Molybdenite.	Opal.	Silver. *Kg.*	Tin Ore.	Tungsten Ore.
1902...........	(*c*) 42	$35,000	21,813	2,118	56
1903...........	(*c*) 24	36,500	19,972	3,768	200
1904...........	(*c*) 22	17,750	20,370	3,986	1,564
1905...........	64	15,000	18,716	4,008	1,434
1906...........	108	15,000	24,357	4,900	785
1907...........	68	15,000	28,662	5,222	627
1908...........	89	12,500	36,200	4,903	426
1909...........	94	10,000	31,140	3,379	617
1910...........	108	15,000	26,787	3,000	869
1911...........	(*c*)232	15,000	17,076	3,140	548
1912	104	14,600	17,712	3,284	636
1913...........	68	14,600	18,817	4,251	364
1914...........	79	9,700	7,899	2,119	245
1915..	99	2,500	7,457	2,160	425
1916...........	82	2,500	7,561	1,734	376

(*a*) From *Annual Reports* of the Under Secretary of Mines, Queensland. (*b*) Where gold is reported, £1 = $4.866. (*c*) Includes bismuth and some tungsten.

MINERAL PRODUCTION OF SOUTH AUSTRALIA
(In metric tons or dollars) (*a*)

Year.	Copper.		Gold. (*b*)	Iron Ore.	Lead.	Lime-stone.	Phosphate Rock.	Salt.	Other Metals and Minerals.
	Ore.	Metal.							
1904.....	3,100	6,378	$369,938	47,434	....	44,135	3,048	40,640	$990
1905.....	2,604	6,653	223,121	85,835	53	45,210	5,080	33,020	6,305
1906.....	535	8,339	131,382	76,430	51	32,451	5,944	55,880	11,045
1907.....	....	8,058	99,948	85,954	....	31,598	8,128	76,200	12,500
1908.....	....	5,718	59,852	89,412	....	29,973	11,177	76,204	22,500
1909.....	1,250	5,788	146,982	16,379	142	13,986	3,833	52,232	19,365
1910.....	....	5,184	136,248	46,939	406	18,898	5,283	54,862	68,000
1911 (*a*)..	....	6,017	72,990	42,976	....	29,159	5,893	66,040	56,600
1912.....	....	6,395	136,248	42,877	....	51,412	6,198	65,338	51,044
1913.....	....	7,174	134,275	61,669	....	45,038	6,049	66,083	104,906
1914.....	....	6,996	129,343	43,324	....	54,955	6,184	66,083	179,425
1915.....	....	7,851	125,689	241,252	....	72,895	4,689	65,066	207,140
1916.....	....	7,400	160,578	191,468	....	75,885	5,096	67,506	171,615

(*a*) From *Review of Mining Operations*, by Hon. Richard Butler, Adelaide, 1911. (*b*) Where gold is reported, £1 = $4.866.

MINERAL PRODUCTION OF TASMANIA (*a*)
(In metric tons or dollars) (*b*)

Year.	Coal.	Copper Ore.	Blister Copper.	Gold. (*b*)	Iron Ore.	Lead-Silver Ore.	Tin Ore.
1903.......	49,856	3,891	6,791	$1,237,925	6,076	43,103	2,414
1904.......	62,090	(*d*)	8,826	1,362,587	6,950	51,959	2,104
1905.......	52,825	(*d*)	9,919	1,520,101	6,401	76,424	3,953
1906.......	53,742	2,270	8,847	1,240,650	2,642	88,513	4,545
1907.......	59,833	1,261	8,378	1,350,836	3,048	91,216	4,412
1908.......	62,044	1,204	8,974	1,179,950	3,657	62,022	4,593
1909.......	67,224	1,613	8,472	951,005	*Nil.*	81,668	4,583
1910.......	83,763	682	8,324	765,784	*Nil.*	52,047	3,760
1911.......	57,980	2,323	6,118	628,375	*Nil.*	62,489	4,016
1912.......	54,366	1,414	5,218	784,320	*Nil.*	91,570	3,773
1913.......	55,960	2,000	4,645	690,369	*Nil.*	84,677	4,077
1914.......	61,807	3,343	7,634	542,437	*Nil.*	11,758	2,616
1915.......	65,612	67	8,031	383,450	(*e*)13,049	10,556	2,642
1916.......	56,470	98	6,406	326,372	(*e*)14,230	11,410	2,901

(*a*) From *Statistics of the Colony of Tasmania.* (*b*) Where value of gold is reported, £1 = $4.866. (*c*) Included with lead-silver ore. (*d*) Not reported. (*e*) Iron pyrite.

MINERAL PRODUCTION OF NEW ZEALAND (*a*) (*b*)
(In metric tons or dollars) (*c*)

Year.	Anti-mony.	Chrome Ore.	Coal.	Coke.	Copper Ore.	Gold. (*c*)	Kauri-gum.	Manga-nese Ore.	Silver. *Kg.*
1903...	....	....	1,442,987	......	6	$9,916,086	9,507	71	28,364.3
1904...	....	....	1,562,520	......	....	9,671,180	9,203	196	34,042.3
1905...	....	....	1,611,207	15	4	10,189,093	10,883	55	36,695.0
1906...	....	....	1,757,284	5	....	11,050,219	9,300	16	43,251.5
1907...	100	....	1,860,397	15	57	9,865,766	8,847	5	48,603.5
1908...	5	....	1,890,844	2	13	9,755,303	5,618	*Nil.*	53,834.8
1909...	2	*Nil.*	1,941,923	23	5	9,765,575	8,382	6	56,410.0
1910...	*Nil.*	*Nil.*	2,232,610	*Nil.*	*Nil.*	9,227,532	8,832	5	52,176.8
1911...	20	*Nil.*	2,099,234	*Nil.*	*Nil.*	9,105,000	7,587	1	40,775.2
1912...	....	....	2,177,615	4	*Nil.*	6,427,422	7,908	....	24,237.8
1913...	....	....	1,919,472	28	....	7,101,822	8,926	....	30,344.6
1914...	....	....	2,313,519	17	3	4,356,856	8,581	....	18,636.4
1915...	....	....	2,244,183	24	....	8,245,695	4,650	....	29,783.6

(*a*) From New Zealand Mines Statement, by the Hon. Roderick McKenzie, Minister of Mines, Wellington. (*b*) The exports are stated to be identical with the production, with the exception of coal. (*c*) Where gold is reported, £1 = $4.866.

MINERAL PRODUCTION OF VICTORIA (*a*)
(In metric tons or dollars)

Year.	Antimony Ore	Coal.	Lignite.	Gold. (*c*)	Building Stone, etc. (*b*)	Tin Ore.
1901.......	*Nil.*	212,678	152	$16,320,029	$225,000	78
1902.......	*Nil.*	228,777	(*b*)	14,899,876	266,975	10
1903.......	5	65,230	5,752	15,860,815	213,245	34
1904.......	20	123,695	*Nil.*	15,824,952	1,496,110	72
1905......	25	157,648	*Nil.*	15,443,438	1,560,090	126
1906......	208	163,201	*Nil.*	15,962,804	1,705,420	108
1907.......	4,575	140,802	*Nil.*	14,377,166	2,023,130	105
1908......	3,740	115,283	*Nil.*	13,867,312	2,138,070	80
1909.......	1,779	130,230	*Nil.*	13,522,400	2,226,220	90
1910......	1,283	374,775	660	11,789,077	2,542,815	42
1911.......	1,116	664,326	6,232	11,789,077	2,820,800	33
1912.......	2,470	598,599	4,076	9,924,032	3,385,070	48
1913.......	6,253	603,811	3,034	9,189,593	3,261,815	58
1914.......	7,730	627,828	2,760	8,540,978	3,485,880	54
1915.......	11,113	588,104	2,864	6,794,771	....	96

(*a*) From Annual Reports of the Secretary for Mines of the Colony. (*b*) Includes bricks, tiles, pottery and salt. (*c*) Where gold is reported, £1 = $4.866. (*e*) Estimated value.

MINERAL PRODUCTION OF WESTERN AUSTRALIA (*a*)
(In metric tons or dollars)

Year	Tungsten Ore.	Coal.	Copper Ore.	Copper and Matte.	Gold. (*b*)	Iron Ore.	Lead Ore.	Silver. *Kg.*	Tin Ore.
1905.....	....	129,402	2,389	....	$ 38,045,366	3,264	*Nil.*	11,189	1,096
1906.....	....	152,151	7,548	(*f*)3,676	35,888,278	1,300	*Nil.*	8,776	1,511
1907.....	....	144,651	19,282	1,628	35,087,500	1,112	(*d*) 214	5,887	(*e*) 1,529
1908.....	....	178,061	8,427	486	34,061,426	*Nil.*	(*d*) 526	5,240	(*e*) 1,118
1909.....	1	217,741	7,071	846	32,973,349	*Nil.*	(*d*) 214	5,500	(*e*) 703
1910.....	2	266,361	6,410	1,301	30,397,162	10	252	5,478	509
1911.....	10	253,900	9,974	832	28,331,272	*Nil.*	1,575	5,215	502
1912....	*Nil.*	299,815	9,689	28	26,511,841	*Nil.*	1,898	5,144	666
1913.....	(*g*)1	319,048	(*g*)4,411	(*g*)83	27,160,557	*Nil.*	(*g*)3,222	5,848	(*h*)496
1914....	(*g*)0.5	324,530	(*g*)3,978	(*g*)186	25,484,960	*Nil.*	(*g*)3,642	6,005	(*gh*)368
1915.....	(*g*)0.3	291,444	(*g*)749	(*g*)1,063	25,012,349	*Nil.*	(*g*)2,931	6,909	(*gh*)436

(*a*) From the *Report of the Department of Mines of Western Australia.* (*b*) £1 = $4.866 (*d*) Silver-lead and lead ore. (*e*) Includes ingots. (*f*) Total in previous years. (*g*) Exports (*h*) Ore and ingot.

MINERAL IMPORTS OF AUSTRALIA (*a*)
(In metric tons, cwt. of 112 lb., or dollars; £1 = $5) (*b*)

Year.	Cement. *Cwt.*	Coal.	Coke.	Copper Ore. *Cwt.*	Gold. (*b*)				
					Ore.	Bullion.	Specie.	Foil. (*c*)	Total Value.
1906	793,928	15,816	6,202	873	$93,116	$10,053,463	$397,990	$53,356	$10,597,925
1907	513,326	14,973	9,981	3,652	136,520	6,942,940	48,499	45,283	7,173,245
1908	915,033	14,833	10,368	3,959	42,855	4,625,498	70,197	....	4,738,550
1909	848,337	16,144	44,668	4,533	35,687	4,865,436	56,280	118,240	5,075,643
1910	1,612,004	314,393	17,161	23,027	35,712	4,653,044	126,556	....	4,815,312
1911	1,670,117	10,498	22,608	10,201	62,951	7,707,919	124,248	....	7,895,118
1912	2,603,792	16,152	15,839	18,449	93,885	5,478,177	1,190,890	....	6,762,952
1913	2,511,828	4,928	27,304	25,085	118,263	5,699,945	910,064	201,645	6,929,917
1914(*e*)	1,040,494	14,085	10,887	11,736	71,311	2,670,213	973,200	....	3,714,724
1915(*f*)	1,407,099	13,580	15,852	14,037	112,035	2,105,421	16,773	....	2,234,229
1916	1,516,858	6,186	1,734	16,257	167,005	2,721,690	33,065	194,435	2,949,190

Year.	Graphite. *Cwt.*	Iron and Steel.			Lead Mfrs. *Cwt.*	Petroleum Products.		
		Bars, Rods Girders, Sheets, etc. *Cwt.*	Galvanized Plates and Sheets. *Cwt.*	Pig and Scrap. *Cwt.*		Kerosene. *Gal.*	Benzine, Gasoline, etc. *Gal.*	Paraffin.
1906...	6,531	1,878,851	1,245,211	1,220,236	3,930	16,106,083	488,961	2,887
1907...	6,991	2,261,694	1,502,790	1,276,566	2,940	19,273,955	683,679	2,757
1908...	£6,705	2,376,017	(*d*)1,253,624	820,834	2,703	17,154,940	782,859	1,560
1909...	£8,965	2,559,798	(*d*)1,658,291	1,178,219	19,338	19,924,622	884,703	2,772
1910...	£9,951	3,663,386	(*d*)2,131,911	1,073,933	9,111	19,660,890	1,339,381	3,963
1911...	£7,782	4,215,986	(*d*)2,177,961	1,574,439	2 120	19,378,540	1,772,840	3,321
1912...	£8,629	4,933,414	(*d*)2,416,367	1,719,585	955	24,292,539	12,294,617	2,832
1913...	£9,785	5,070,590	(*d*)2,196,865	1,535,030	2,075	19,288,122	8,812,771	2,803
1914 (*e*)	£5,319	2,377,790	(*d*)1,265,429	833,008	7,676	12,231,752	8,853,386	1,815
1915 (*f*)	£8,359	3,236,889	1,676,033	1,352,011	3,820	20,444,196	12,446,797	2,790
1916...	£12,227	1,362,376	1,238,623	631,133	1,208	24,857,800	12,464,868	7,014

Year.	Potassium Nitrate. *Cwt.*	Quick-silver.	Salt. *Cwt.*	Silver. (*b*)			Sulphur. *Cwt.*	Zinc, Bar and Sheet. *Cwt.*
				Ore. *Cwt.*	Bullion. *Kg.*	Specie.		
1906.....	8,112	78.6	326,042	380	9756.2	$684,958	269,704	£35,142
1907.....	8,571	59.5	409,852	2	113.7	1,829,309	264,060	27,346
1908.....	6,036	56.4	390,535	....	189.8	1,019,738	420,098	27,449
1909.....	6,894	58.4	273,442	1,972	622.2	157,352	405,396	58,451
1910.....	7,016	57.6	444,081	14,609	1,411.7	1,615,775	357,332	70,339
1911.....	10,257	42.4	753,849	1,734	1,115.8	1,648,430	386,764	86,362
1912.....	10,127	52.8	468,507	3,836	1,580.3	1,350,870	465,643	61,736
1913.....	10,552	46.0	533,055	10,396	1,180.4	861,500	603,865	41,650
1914(*e*)...	6,349	20.9	139,024	....	622.5	546,481	246,586	21,147
1915(*f*)...	7,500	24.0	382,160	319	586.1	2,062,386	421,947	29,193
1916.....	7,522	34.1	270,475	....	174.2	1,058,988	825,648	12,303

(*a*) From Trade and Customs Returns, Commonwealth of Australia. Previous to 1900 each Colony reported its own imports and exports. (*b*) Where gold or silver values are reported, £1 = $4.866. (*c*) Includes silver and other foils. (*d*) Includes ungalvanized corrugated. (*e*) First six months. (*f*) Fiscal year ending June 30th.

MINERAL EXPORTS OF AUSTRALIA (*a*)

(In metric tons, cwt. of 112 lb., or dollars; £1 = $5)

Year.	Alunite. *Cwt.*	Anti-mony Ore. *Cwt.*	Bis-muth Ore. *Cwt.*	Cement. *Cwt.*	Chrome Ore. *Cwt.*	Coal.	Coke.	Co-balt Ore. *Cwt.*	Copper.	
									Ore. (*f*) *Cwt.*	Ingot and Matte. (*Cwt.*)
1906...	37,120	66,288	1,574	80,368	(*c*)	2,094,911	11,382	3	33,476	744,357
1907...	41,750	74,440	653	75,600	54,503	2,690,070	35,063	....	157,071	853,236
1908...	21,640	23,931	1,396	49,116	22,300	2,601,962	28,068	....	103,694	765,298
1909...	73,795	14,976	1,763	23,585	....	1,608,173	24,798	280	162,904	676,664
1910...	23,290	12,796	1,456	34,259	....	1,730,473	10,457	186	260,597	765,176
1911...	20,274	17,985	2,307	45,247	....	1,714,959	8,543	....	264,688	806,005
1912...	68,500	30,894	610	27,724	453	2,186,946	9,852	....	259,690	876,773
1913...	44,700	51,007	588	18,221	....	2,132,201	8,163	....	177,757	846,411
1914(*g*)	24,200	30,661	151	23,813	....	1,182,548	2,636	....	62,658	392,005
1915(*h*)	52,400	50,316	1,295	24,591	....	1,394,151	14,563	....	142,363	669,189
1916(*h*)	12,800	74,631	2,602	27,345	....	944,971	25,660	....	89,382	737,841

Year.	Gold. (b)				Iron and Steel Bars, Rods, etc. *Cwt.*	Lead.		
	Ore.	Bullion.	Specie.	Total Value.		Pig and Matte. *Cwt.*	Argentiferous. *Cwt.*	Manufactures *Cwt.*
1906....	$20,296	$24,113,950	$57,981,723	$82,115,969	216,862	1,018,856	781,426 (h)	20,407
1907....	17,513	(e) 19,639,502	33,370,240	53,027,255	194,237	1,006,945	767,262	21,765
1908....	20,539	(e) 18,924,716	50,794,544	69,739,799	170,636	1,483,415	648,784	20,161
1909....	270,131	(e) 17,265,872	26,028,555	43,564,558	158,468	808,297	573,072	14,067
1910....	429,288	(e) 12,070,522	16,598,747	23,098,557	154,846	1,326,702	473,556	13,350
1911....	327,107	(e) 10,456,322	47,831,267	58,614,696	116,893	1,358,308	397,342	14,610
1912....	340,474	(e) 9,135,487	50,801,322	60,277,283	138,061	1,438,681	502,264	17,916
1913....	371,257	(e) 6,695,757	10,184,007	17,251,021	184,433	1,529,075	524,513	14,989
1914 (g).	45,825	(e) 2,119,722	4,882,690	7,048,235	71,337	676,457	376,587	10,239
1915 (h).	255,883	(e) 3,325,439	9,447,081	13,028,403	179,122	1,427,455	737,416	14,190
1916 (h).	125,144	(e) 5,053,472	46,308,413	51,487,029	18,675	2,458,134	195,565	10,868

Year.	Molybdenum Ore. *Cwt.*	Salt. *Cwt.*	Shale, Oil.	Silver.		Tin.		Zinc, Bar and Sheets. *Cwt.*
				Ore. (d) *Cwt.*	Bullion. *Kg.*	Ore. *Cwt.*	Block. *Cwt.*	
1906.....	1,867	208,750	7,702	1,010,707	201,175	51,793	130,120	£4,820
1907.....	2,025	189,194	5,777	907,790	294,673	65,005	131,407	1,769
1908.....	2,116	240,348	19,173	1,137,746	326,249	49,409	121,979	307
1909.....	1,055	230,486	3,983	(f) 1,914,479	210,570	(f) 57,902	111,262	167
1910.....	1,972	184,892	9,307	(f) 2,520,652	233,494	(f) 48,209	87,529	1,807
1911.....	1,876	63,607	6,344	(f) 3,226,043	(e) 218,387	(f) 55,721	82,935	1,050
1912.....	2,873	123,779	290	(f) 2,395,267	(e) 238,947	(f) 64,704	77,501	15,971
1913.....	2,684	134,863	449	(d) (f) 3,377,901	(e) 252,219	(f) 89,384	68,392	12,236
1914 (g)..	2,009	47,560	283	(d) (f) 1,701,932	(e) 126,139	(f) 42,616	27,624	....
1915 (h)..	2,080	111,001	457	(d) (f) 553,173	(e) 213,102	(f) 42,845	29,891	54,099
1916 (h)..	2,569	312,525	80	(d) (f) 195,565	(e) 205,024	(f) 48,116	68,690	46,132

(a) From Trade and Customs Returns, Commonwealth of Australia.—Note. Previous to 1900 each Colony reported its own exports separately. (b) Where gold or silver values are reported, £1 = $4.866. (c) Included with iron ore. (d) Includes lead ore. (e) Includes that contained in matte. (f) Includes concentrates. (g) First six months. (h) Fiscal year ending June 30th.

AUSTRIA-HUNGARY

In the following tables the mineral and metal productions of the two Kingdoms are reported separately, together with that of Bosnia and Herzegovina. Exports and imports are reported jointly.

MINERAL AND METALLURGICAL PRODUCTION OF AUSTRIA (*a*)
(In metric tons)

Year.	Alum.	Alum and Pyritic Shale.	Antimony.		Asphalt and Asphaltic Rock.	Bismuth Ore.	Coal.	
			Ore.	Metal.			Bituminous.	Lignitic.
1900.......	620	3,004	201	153	924	4.0	10,992,515	21,539,917
1901.......	442	2,551	126	114	561	16.0	11,738,840	22,473,510
1902.......	62	2,866	18	24	927	8.0	11,045,039	22,139,683
1903.......	*Nil*	2,978	41	14	1,298	9.7	11,498,111	22,157,521
1904.......	*Nil*	2,337	103	36	1,435	1.7	11,868,245	21,987,651
1905.......	*Nil*	1,657	1,673	90	4,363	1.7	12,585,263	22,692,076
1906.......	*Nil*	1,020	1,071	*Nil*	2,840	2.7	13,473,307	24,167,714
1907.......	*Nil*	*Nil*	910	207	3,858	*Nil*	13,850,420	26,262,110
1908.......	*Nil*	*Nil*	193	162	3,695	*Nil*	13,875,382	26,728,926
1909.......	*Nil*	*Nil*	450	*Nil*	2,975	*Nil*	13,713,043	26,043,716
1910.......	*Nil*	*Nil*	225	*Nil*	1,066	*Nil*	13,773,985	25,132,855
1911.......	*Nil*	*Nil*	270	....	1,740	....	14,379,817	25,265,334
1912.......	....	....	4,520	13	4,234	....	15,797,890	26,283,690
1913.......	....	....	1,270	....	3,026	....	16,459,889	27,378,332

Year.	Copper.			Copperas.	Gold.		Graphite.	Iron.	
	Ore.	Metal.	Sulphate.		Ore.	Bullion.		Ore.	Pig & Cast.
1900.......	5,825	881	234	474	227	$47,183	33,663	1,894,458	1,000,207
1901.......	7,406	776	256	472	143	31,234	29,992	1,963,246	1,030,260
1902.......	8,455	914	248	271	74	4,652	29,527	1,744,498	991,827
1903.......	8,188	961	310	298	2,148	5,316	29,590	1,715,984	970,832
1904.......	10,701	889	808	414	12,653	47,183	28,620	1,719,219	988,364
1905.......	10,677	870	540	116	35,937	133,218	34,416	1,913,782	1,119,614
1906.......	20,255	877	578	154	33,033	83,401	38,117	2,253,662	1,222,230
1907.......	10,400	592	579	*Nil*	30,711	92,471	49,425	2,540,118	1,383,524
1908.......	8,381	683	556	*Nil*	28,907	98,504	44,425	2,632,407	1,466,897
1909.......	11,826	985	591	70	29,709	98,295	40,710	2,490,277	1,465,051
1910.......	8,005	1,468	715	30	31,744	118,895	33,131	2,627,513	1,504,786
1911.......	10,974	1,760	767	*Nil*	29,647	134,840	41,599	2,765,815	1,596,148
1912.......	17,354	3,057	884	40	30,192	134,543	45,375	2,926,686	1,759,850
1913.......	16,353	3,685	897	40	35,994	186,714	49,456	3,039,324	1,757,864

Year.	Lead.			Manganese. Ore.	Mineral Paint.	Petroleum.	Quicksilver.		Salt.
	Ore.	Pig.	Litharge.				Ore.	Metal.	
1900......	14,314	10,650	1,288	8,804	2,828	347,213	94,727	510	330,277
1901......	16,688	10,161	1,317	7,796	1,701	404,662	97,360	525	333,238
1902......	19,055	11,264	1,023	5,646	1,486	520,845	90,040	511	311,806
1903......	22,196	12,162	923	6,179	1,691	672,508	83,321	523	359,015
1904......	22,514	12,645	783	10,189	1,829	823,943	88,279	536	369,877
1905......	23,339	12,968	865	13,788	798	794,391	86,856	520	343,375
1906......	19,683	14,846	1,059	13,402	943	737,194	91,494	526	376,212
1907......	22,792	13,598	863	16,756	1,091	1,725,808	89,370	527	395,053
1908......	21,513	12,669	1,010	16,656	475	1,718,030	90,145	572	388,133
1909......	20,550	12,941	840	18,045	620	2,086,342	92,337	585	359,801
1910......	22,841	15,476	602	15,694	698	1,766,018	100,899	603	345,629
1911......	23,845	18,097	318	15,954	2,902	1,487,842	111,018	704	342,732
1912......	27,952	19,993	301	12,471	2,960	1,144,133	117,780	763	365,789
1913......	25,751	22,312	305	16,540	2,999	1,081,090	130,608	820	337,563

Year.	Silver.		Sulphuric Acid.	Sulphur. Ore.	Tin.		Tungsten Ore.	Uranium.		Zinc.	
	Ore.	Bullion. *Kg.*			Ore.	Block.		Ore.	Salts.	Ore.	Spelter.
1900.	21,641	39,572	7,067	862	51	40	50	52.0	11.3	38,243	6,742
1901.	21,363	40,205	7,073	4,911	42	49	45	48.0	13.0	36,072	7,558
1902.	22,288	39,544	8,781	3,721	47	50	45	46.0	10.0	31,927	8,309
1903.	21,958	39,812	9,105	4,475	57	34	49	45.0	5.8	29,544	8,949
1904.	21,948	39,032	8,742	6,288	77	38	52	17.0	11.4	29,226	9,159
1905.	21,047	38,453	1,007	8,407	52	53	59	16.0	13.9	29,983	9,326
1906.	21,944	38,940	745	15,125	55	42	56	16.0	10.3	32,037	10,804
1907.	22,636	38,742	*Nil*	24,099	53	47	44	11.0	11.2	31,970	11,208
1908.	22,241	39,867	*Nil*	17,429	68	39	37	9.0	8.4	31,266	12,770
1909.	21,102	39,002	*Nil*	12,725	36	52	39	18.0	10.2	33,955	11,688
1910.	23,629	49,692	....	15,839	37	40	40	6.5	10.3	34,637	12,458
1911.	24,143	50,244	....	15,805	944	15	45	5.8	6.8	32,166	15,766
1912.	21,794	49,355	....	13,996	606	13	66	11.0	5.4	34,675	17,298
1913.	19,937	54,434	....	10,561	939	11	52	11.2	4.5	34,225	19,508

(*a*) From the *Statistisches Jahrbuch des K. K. Ackerbau-Ministeriums.*

MINERAL AND METALLURGICAL PRODUCTION OF HUNGARY (*a*)
(In metric tons or dollars; 1 crown = $0.203)

Year.	Antimony.		Asphalt	Asphaltic Rock.	Bismuth.	Carbon Bisulphide.	Coal.			
	Ore.	Regulus.					Bituminous. (*d*)	Lignite. (*d*)	Coke.	Briquets.
1901...	(*b*) 323	706	2,878	25,161	1.6	2,087	1,365,270	5,179,829	10,975	40,182
1902...	(*b*) 748	683	2,774	24,873	0.9	2,320	1,162,785	5,132,053	8,204	88,069
1903...	(*b*) 205	732	2,422	21,552	1.5	2,357	1,233,410	5,271,781	9,442	101,197
1904...	1,080	1,007	2,221	17,660	0.9	2,512	1,155,320	5,519,349	5,103	103,481
1905...	949	756	173	19,372	1.4	2,760	919,193	6,015,452	69,303	144,697
1906...	1,807	954	4,111	34,664	2.0	2,756	1,103,529	6,229,712	79,930	151,657
1907...	2,035	841	3,920	33,096	0.4	2,950	1,038,819	6,408,322	97,447	154,783
1908...	1,316	670	4,818	72,972	(*c*)	2,966	982,017	7,034,499	141,954	109,178
1909...	1,971	695	5,054	....	......	3,086	1,397,424	7,658,719	157,415	117,594
1910...	1,939	782	4,994	....	......	3,245	1,302,103	7,734,166	156,048	108,873
1911...	2,616	892	3,861	....	......	3,488	1,290,182	8,154,560	145,104	118,412
1912...	8,380	859	4,460	....	......	3,692	1,302,405	8,287,871	149,913	118,505
1913...	11,017	1,048	3,025	45,860	(*f*)25	3,148	1,319,918	8,954,133	160,073	117,186
1914...	....	....	....	....	......	....	909,882	....	128,118	112,040

Year.	Copper.	Copperas.	Gold.	Iron.			Lead.		Litharge.	Manganese. Ore.
				Ore. (*d*)	Pig.	Cast.	Ore.	Pig.		
1901...	162	805	$2,189,692	1,557,300	430,686	20,640	(*b*) 10	2,029	238	4,591
1902...	89	909	2,260,135	1,562,238	416,835	18,569	(*b*) 20	2,244	219	7,237
1903...	45	982	2,243,521	1,439,132	396,674	18,875	(*d*)3,698	2,057	257	5,311
1904...	63	1,277	2,437,988	1,524,036	370,297	17,203	(*d*)3,922	2,104	710	11,527
1905...	73	920	2,439,451	1,661,358	403,719	17,563	686	2,146	209	5,708
1906...	69	1,306	2,487,156	1,698,291	402,527	17,164	564	1,925	698	7,176
1907...	85	1,212	2,330,292	(*e*)622,518	423,134	17,103	8	1,468	441	8,198
1908...	166	1,372	2,189,801	(*e*)727,019	505,559	17,415	3	1,544	190	10,601
1909...	265	1,414	1,813,024	1,965,487	514,853	15,577		1,590	625	11,921
1910...	214	1,313	2,022,032	1,905,749	487,421	14,635	91	2,077	570	13,270
1911...	208	849	2,125,241	1,950,231	502,460	15,990	239	1,583	391	14,755
1912...	242	1,364	1,898,771	1,991,162	541,659	11,180	1,212	1,605	477	13,833
1913...	405	627	1,945,958	2,059,076	608,966	13,986	488	1,137	412	19,006
1914...	358	....	....	1,722,340	494,441	....	....	1,368	......	11,413

Year.	Mineral Paints.	Petroleum.	Pyrite.	Quicksilver. Kg.	Salt.	Silver. Kg.	Sulphur.	Sulphuric Acid.	Zinc.	
									Ore. (b)	Spelter.
1902...	283	4,347	106,490	44,600	217,079	23,020	105	1,193	364	....
1903...	263	3,010	96,619	43,700	214,536	19,281	135	1,543	46	26
1904...	273	2,134	97,148	45,169	230,943	16,352	143	1,329	203	....
1905...	196	471	106,848	36,000	238,642	15,946	135	1,410	173	....
1906...	221	2,692	112,623	50,100	245,402	13,642	133	1,457	243	146
1907...	259	2,404	99,503	40,400	(c)	12,695	(c)	1,232	(c)	(c)
1908...	294	2,427	95,824	78,000	(c)	12,612	144	1,444	135	(c)
1909..	63	2,590	98,971	71,500	231,182	10,932	131	1,307	(0)	....
1910...	55	2,501	92,464	90,000	230,315	12,547	128	1,334	280	....
1911...	69	2,191	96,755	79,700	239,006	10,806	51	938	106	....
1912...	105	2,793	103,809	84,979	270,929	10,782	83	1,311	778	....
1913...	57	2,105	106,629	88,800	256,448	8,696	42	555	407	....
1914...	....	....	102,370	....	....	....	....	....	......	....

(a) From the *Annuaire Statistique Hongrois.* (b) Includes only that part of the crude output that was not smelted into a refined product. (c) Not reported. (d) Total production. (e) Exported. (*f*) Kilograms.

MINERAL AND METALLURGICAL PRODUCTION OF BOSNIA AND HERZEGOVINA (a)
(In metric tons)

Year.	Chrome Ore.	Copper.		Iron.		Lignite.	Manganese Ore.	Pyrite.	Quicksilver.	Salt.
		Ore.	Metal.	Ore.	Pig.					
1902...	270	3,657	166	133,348	43,992	424,753	5,760	5,170	7.2	17,348
1903...	147	1,073	191	114,059	39,833	467,962	4,538	6,589	8.1	18,459
1904...	279	640	115	127,297	47,678	483,617	1,114	10,412	8.1	18,021
1905...	186	670	39	122,540	43,074	540,237	4,129	19,045	10.0	(b)
1906...	320	765	25	136,513	45,660	594,172	7,651	11,347	5.1	22,671
1907...	310	245	*Nil.*	150,684	48,946	621,179	7,000	7,229	1.2	21,148
1908 (c)	315	(b)	*Nil.*	150,075	48,900	630,500	6,000	(b)	*Nil.*	22,100
1909 (c)	310	(b)	*Nil.*	145,200	48,850	675,400	5,000	(b)	*Nil.*	22,500
1910...	320	(b)	*Nil.*	132,720	48,841	706,659	4,000	571	*Nil.*	23,579
1911...	250	(b)	*Nil.*	140,283	44,354	769,763	3,600	3,118	*Nil.*	22,591
1912...	200	....	*Nil.*	150,420	53,270	852,920	4,650	6,216	*Nil.*	23,124
1913...	305	....	......	220,131	53,587	841,140	4,700	7,701	....	24,176
1914...	211	....	......	178,830	44,078	806,831	4,120	4,459	....	25,730

(a) From *Oestr. Zeit. f. B.-u. H.* (b) Not reported. (c) Estimated.

MINERAL IMPORTS OF AUSTRIA-HUNGARY (a)
(In metric tons or dollars; 5 Crowns = $1)

Year.	Alum.	Aluminium and Alloys.	Aluminium Sulphate and Chloride.	Antimony.		Arsenic. (b)	Asbestos.	
				Ore.	Regulus. Kg.		Crude. (c)	Manufactures.
1900.....	430	154	1,435	46	23,000	320	1,085	1,238
1901.....	413	153	1,882	27	1,500	351	1,678	1,032
1902.....	537	151	2,161	40	18,200	351	2,038	798
1903.....	508	150	2,670	42	87,200	371	3,395	1,221
1904.....	602	231	2,346	64	21,000	384	2,517	1,240
1905.....	774	477	2,775	42	24,700	342	5,962	208
1906(*f*)..	513	216	2,840	79	38,900	83	7,025	111
1907.....	545	255	3,200	231	89,900	325	5,729	180
1908.....	567	323	2,606	304	128,200	349	9,484	139
1909.....	359	418	1,831	95	80,100	370	12,003	200
1910.....	589	303	1,474	96	121,800	416	11,602	250
1911.....	375	516	1,317	98	124,600	377	16,071	276
1912.....	253	1,224	1,396	91	49,000	24	24,615	338
1913.....	454	589	1,334	....	....	47	17,575	248

Year.	Asphalt. Crude Rock.	Asphalt. Mastic and Bitumen.	Barytes.	Borax. Crude, and Boric Acid.	Borax. Refined.	Cement.	Chloride of Lime.	Chrome Ore.
1900	8,301	1,564	5,945	3,056	93	25,747	3,326	2,823
1901	5,702	1,106	6,336	1,687	233	23,559	3,326	860
1902	5,732	1,273	6,266	2,168	174	18,658	2,596	2,668
1903	5,871	1,272	7,057	2,192	150	23,256	2,791	2,121
1904	8,211	1,064	6,238	2,752	142	20,259	3,407	1,209
1905	8,553	1,139	6,187	3,099	205	21,950	1,847	2,305
1906(f)	13,381	895	9,654	3,519	126	21,833	2,491	1,612
1907	9,394	1,637	11,669	3,763	138	23,697	2,534	2,795
1908	11,678	1,305	11,241	4,105	158	39,135	2,395	1,837
1909	9,113	1,309	13,940	3,240	139	53,262	3,105	2,223
1910	15,897	1,101	21,486	5,284	166	81,251	1,885	1,271
1911	18,394	1,990	20,501	4,407	193	80,613	3,131	2,217
1912	25,111	4,295	21,375	4,286	482	83,630	2,802	4,329
1913	24,794	1,011	23,350	5,652	356	61,261	3,097	2,845

Year.	Kaolin and Feldspar.	Coal. Bituminous.	Coal. Lignitic.	Coke.	Copper. Ore.	Copper. Bullion and Scrap.	Copper. Bars, Sheets, Wire, etc.	Copper Sulphate.
1900	6,847	6,242,939	67,740	620,776	16	18,970	121	3,516
1901	7,687	5,827,332	22,253	612,209	112	17,504	83	2,822
1902	9,085	5,766,377	29,601	547,406	100	18,498	149	2,839
1903	9,940	5,907,660	30,007	519,281	209	18,701	89	3,526
1904	10,854	6,190,030	30,001	548,272	1,107	22,532	89	4,508
1905	13,656	6,418,042	36,000	554,147	1,397	22,652	73	3,791
1906 (f)	13,219	5,942,897	17,464	406,088	267	20,943	481	1,597
1907	17,961	9,692,645	23,699	677,750	44	26,181	818	3,981
1908	17,417	9,995,415	30,433	851,099	121	33,270	1,140	8,402
1909	16,185	10,482,264	38,679	701,281	13	30,606	568	4,129
1910	17,817	9,864,462	37,867	670,089	49	32,217	926	3,445
1911	22,828	10,873,799	34,381	702,707	716	37,251	538	6,598
1912	24,628	11,848,535	34,871	(h)915,547	765	45,460	850	16,131
1913	22,467	13,689,149	33,097	933,669	150	36,451	572	6,937

Year.	Copperas.	Cryolite.	Fluorspar.	Gold. (d) Bullion.	Gold. (d) Coin.	Graphite.	Gypsum. Crude.	Gypsum. Burned.	Hydrochloric Acid.
1900	343	342	5,649	$1,111,831	$7,230,251	302	1,348	15,462	577
1901	269	428	5,774	13,865,103	20,353,592	318	1,405	15,830	576
1902	274	447	5,902	14,509,019	15,695,960	221	1,588	16,430	588
1903	155	521	5,445	9,825,200	9,817,283	405	1,969	18,655	603
1904	238	313	7,061	12,703,740	8,586,394	423	2,384	19,387	459
1905	169	220	7,601	1,047,792	9,204,968	735	1,553	21,286	656
1906(f)	186	217	7,795	989,604	5,229,591	854	4,104	10,308	476
1907	187	613	8,779	1,106,002	5,755,918	934	5,813	11,981	629
1908	74	564	7,359	7,303,982	7,969,538	755	4,993	10,842	924
1909	56	556	8,106	36,744,037	8,631,453	660	4,907	10,410	898
1910	89	703	8,292	1,399,400	4,485,600	1,124	5,733	20,390	635
1911	66	944	9,446	3,163,554	1,902,798	1,173	6,616	16,489	612
1912	43	1,053	6,396	667,350	1,516,911	1,834	10,585	24,944	1,115
1913	53	635	10,204	5,855,085	3,626,938	1,499	8,696	24,659	975

Year.	Iron.				Lead.				
	Ore.	Pig and Old.	Manufactures.	Iron and Steel Bars, Sheets, Wire, etc.	Ore.	Pig, Alloys, Crude.	Litharge.	Red and Yellow.	White.
1900	233,156	95,530	$4,533,599	10,313	501	7,916	141	354	106
1901	218,476	90,287	4,443,670	10,902	1,270	10,722	189	433	135
1902	197,525	43,314	4,304,818	11,584	1,879	8,706	149	428	221
1903	217,979	47,354	4,508,224	11,025	1,355	9,190	141	423	173
1904	182,515	35,091	4,976,342	9,402	1,436	7,917	146	372	138
1905	228,149	49,383	5,722,976	33,256	247	7,282	101	349	88
1906(*f*)	232,558	57,341	6,153,698	5,085	189	11,732	82	310	75
1907	390,322	151,848	(*g*)29,520	29,268	204	12,547	98	381	126
1908	423,940	224,740	(*g*)45,235	88,396	559	17,116	161	616	201
1909	374,088	147,459	(*g*)48,344	34,025	7,560	20,697	230	599	57
1910	307,190	185,604	51,869	44,277	6,354	17,065	411	574	139
1911	469,552	112,907	53,590	32,687	1,200	17,238	299	622	108
1912	628,867	244,532	64,621	48,137	3,240	16,961	403	448	94
1913	942,312	188,324	....	....	8,055	12,455	402	367	113

Year.	Magnesium Chloride.	Manganese Ore.	Millstones.	Mineral Paints.	Nickel, Old and Crude.	Nickel and Cobalt Ores	Nitric Acid.	Peat and Peat Coke.
1900	2,100	7,016	1,672	4,958	258	406	36	2,664
1901	2,529	6,367	1,595	5,109	277	788	22	2,896
1902	2,621	15,595	1,410	4,831	265	225	90	3,234
1903	3,118	38,529	1,395	4,733	268	385	7	3,097
1904	2,997	35,357	1,282	5,563	402	656	24	2,676
1905	3,495	30,483	1,467	6,018	632	391	14	2,432
1906(*f*)	4,050	33,406	1,176	4,660	773	*Nil.*	12	1,918
1907	5,006	70,067	1,469	6,043	1,192	*Nil.*	12	4,460
1908	5,011	31,023	1,474	5,909	1,521	114	11	6,459
1909	6,095	44,970	1,357	5,773	2,116	*Nil.*	30	5,993
1910	6,616	59,951	1,510	7,340	1,606	*Nil.*	37	5,002
1911	7,171	78,790	1,494	7,157	1,598	0.1	27	5,115
1912	8,344	62,202	2,175	8,468	2,508	1.8	54	6,356
1913	7,799	67,278	2,066	6,984	1,895	....	39	4,264

Year.	Petroleum Products.			Phosphorus and Phosphoric Acid.	Potassium Salts.			Pyrite.
	Crude Oil.	Refined Oil.	Paraffin.		Carbonate.	Chloride.	Chromate.	
1900	20,813	22,963	5,080	204	1,029	3,633	11	60,317
1901	22,545	18,067	5,294	222	1,442	4,356	21	54,202
1902	24,830	15,864	4,238	225	485	3,377	11	60,235
1903	19,710	19,382	2,598	237	197	3,727	9	73,835
1904	20,110	22,715	1,470	193	222	3,557	3	65,397
1905	18,974	24,961	888	222	154	3,864	5	86,338
1906(*f*)	13,522	9,693	403	178	602	3,729	(*e*) 5	87,973
1907	18,345	11,441	524	219	174	4,807	(*e*)38	130,270
1908	3,118	9,705	358	234	324	5,009	(*e*)98	130,793
1909	1,357	9,093	508	231	314	4,782	(*e*)86	141,858
1910	18,977	16,868	457	253	185	5,052	69	153,106
1911	19,070	19,737	632	233	201	3,666	55	150,974
1912	17,874	21,153	546	258	339	5,280	55	186,690
1913	19,125	31,590	299	255	157	5,216	175	130,526

Year.	Quicksilver Kg.	Salt.	Sand.	Silver.		Slag and Slag Wool.	Roofing Slate.
				Bullion. Kg.	Specie.		
1900	1,300	39,822	77,930	29,300	$199,955	....	13,047
1901	2,600	39,625	83,401	41,800	207,669	....	11,555
1902	1,300	46,128	92,617	177,900	237,104	....	14,378
1903	1,600	48,793	94,492	150,400	250,299	....	11,531
1904	2,500	94,103	97,364	36,700	420,413	....	9,170
1905	2,400	......	104,195	36,100	143,152	....	8,852
1906(f)	1,800	32,182	134,526	43,000	200,754	109,827	6,020
1907	1,200	41,660	180,280	88,182	170,228	107,783	7,537
1908	2,000	54,525	177,529	96,700	101,265	115,445	7,178
1909	2,600	75,397	183,169	150,980	172,201	155,812	6,915
1910	2,300	96,936	188,762	161,600	121,000	147,192	9,019
1911	2,900	99,921	225,743	195,000	70,102	147,179	8,060
1912	3,700	113,287	249,766	91,110	78,361	204,946	7,824
1913	4,400	110,923	235,775	148,580	206,032	214,726	6,351

Year.	Sodium Salts.						Sulphur.
	Bi-sulphate.	Carbonate.	Carbonate (Calcined).	Hydrate.	Nitrate.	Sulphate.	
1900	73	104	1,141	1,836	54,559	5,110	27,795
1901	98	77	911	1,280	63,283	4,452	25,300
1902	17	97	312	1,030	39,958	5,997	23,878
1903	13	110	327	956	54,896	6,116	22,625
1904	103	103	1,109	659	54,887	5,409	30,505
1905	167	168	965	475	66,740	5,258	30,227
1906(f)	86	382	303	218	49,862	7,508	26,755
1907	72	153	283	305	57,023	7,342	34,261
1908	32	124	288	358	69,722	7,596	30,985
1909	26	149	297	832	80,533	9,402	28,639
1910	15	224	354	341	81,781	10,150	34,936
1911	5	297	337	297	65,781	10,842	34,916
1912	10	(i)455	260	302	92,838	14,454	40,913
1913	12	247	262	102	93,025	12,682	39,228

Year.	Sulphuric Acid.	Tin. Ingot, Crude, Old, etc.	Whetstones.	Zinc.			
				Calamine and Other Ores.	Spelter.	Bars, Sheets, Wires, etc.	White.
1900	10,643	3,439	3,643	14,181	17,844	667	875
1901	11,712	3,671	3,445	18,403	16,921	579	718
1902	12,474	3,638	3,599	20,723	17,034	651	636
1903	16,148	3,564	3,774	22,344	17,973	746	698
1904	19,878	3,528	4,272	24,039	20,787	731	840
1905	17,320	3,845	4,376	22,890	21,874	568	972
1906(f)	17,020	3,320	4,377	24,014	19,467	595	347
1907	20,430	4,433	5,552	24,289	24,092	604	219
1908	25,251	4,295	5,916	19,366	26,472	1,010	361
1909	27,368	4,587	6,826	24,639	27,148	1,263	349
1910	27,421	4,674	6,915	30,880	29,168	1,898	511
1911	26,630	4,795	8,066	31,357	33,740	388	471
1912	36,714	4,806	6,826	35,376	37,558	1,260	438
1913	24,922	4,214	6,579	52,299	31,841	1,264	392

(a) From *Statistik des Auswaertigen Handels des Oesterreichisch-Ungarischen Zollgebiets.* (b) Includes arsenious acid and sulphide. (c) Includes burned asbestos. (d) The values of gold are figured at the rate of one crown = $0.203. (e) Potassium and Sodium. (f) Last 10 months only. (g) Metric tons. (h) Not including 188,884 tons of briquettes. (i) Includes bicarbonate.

MINERAL EXPORTS OF AUSTRIA-HUNGARY (a)
(In metric tons or dollars; 5 crowns = $1)

Year.	Alum.	Aluminium Sulphate and Chloride.	Antimony.		Arsenic, Metallic Oxide, Orpiment, and Realgar.	Asbestos.		Asphalt.	
			Ore.	Regulus.		Crude.	Manufactured.	Rock and Earth.	Mastic and Bitumen.
1900....	44	164	247	276	65	47	168	1,218	2,177
1901....	55	211	179	385	80	36	165	198	1,909
1902....	102	135	174	290	89	65	275	520	301
1903....	77	14	128	249	63	89	495	921	483
1904....	38	2	200	673	72	290	1,582	403	728
1905....	68	34	178	774	42	330	1,397	1,060	457
1906 (f).	68	80	314	912	66	376	1,708	2,824	799
1907....	75	81	92	698	59	351	630	3,787	771
1908....	147	92	161	527	51	442	450	1,312	1,030
1909....	65	57	97	185	117	264	561	1,800	758
1910....	346	85	54	416	9	262	604	1,545	954
1911....	157	16	77	267	13	141	992	1,845	1,218
1912....	253	7	54	689	2	530	779	1,357	1,920
1913....	454	5	....	....	....	243	1,605	326	2,621

Year.	Barium.		Chloride of Lime.	Cement.	Chrome Ore.	Kaolin and Feldspar.	Coal.		Coke.
	Sulphate (b)	Chloride.					Bituminous.	Lignitic.	
1900...	23	....	192	46,761	22	103,178	815,097	7,864,410	262,793
1901...	55	4,098	738	44,723	62	97,037	748,802	8,076,575	303,651
1902...	64	4,552	426	39,920	51	100,546	691,680	7,888,218	234,911
1903...	52	5,091	674	40,239	100	110,181	754,957	8,027,347	280,395
1904...	74	4,233	254	43,110	36	127,984	815,570	7,588,555	353,695
1905...	26	4,626	978	52,830	46	137,125	903,156	8,035,718	287,790
1906(f)	2,395	4,503	271	64,883	102	133,326	750,420	7,150,339	246,914
1907...	3,119	5,220	308	81,407	161	157,894	849,792	8,876,408	323,243
1908...	2,987	2,974	519	65,597	144	154,146	762,867	8,600,683	183,279
1909...	2,585	3,737	462	63,463	174	150,878	633,253	8,241,723	198,313
1910...	13	4,344	1,213	98,888	140	164,859	615,082	7,492,447	230,735
1911...	12	3,741	1,175	168,321	70	174,493	609,737	7,063,981	299,915
1912...	2,690	3,658	1,518	149,860	95	187,358	655,106	7,442,392	349,384
1913...	753	4,918	2,042	144,596	142	197,693	708,975	7,016,606	369,802

Year.	Fluorspar.	Copper.			Copper Sulphate.	Copperas.	Cryolite.
		Ore.	Crude and Old.	Bars, Sheets, Plates, etc.			
1900..........	45.0	801	471	200	57	748	237
1901..........	6.0	1,042	435	334	23	548	231
1902..........	42.0	1,018	436	381	44	857	363
1903..........	12.0	1,308	1,226	451	45	898	521
1904..........	36.0	574	747	577	50	1,170	574
1905..........	5.0	2,328	1,253	746	49	836	638
1906..........	*Nil.*	341	1,007	816	99	861	*Nil.*
1907(f)........	*Nil.*	489	624	870	11	1,580	*Nil.*
1908..........	7.0	206	1,126	791	63	2,199	*Nil.*
1909..........	12.0	136	1,250	541	40	1,877	*Nil.*
1910..........	4.0	101	977	700	83	2,273	42
1911..........	0.2	126	1,309	1,109	14	2,124	122
1912..........	13.0	516	1,332	1,642	119	3,090	46
1913..........	15.0	182	1,379	1,297	172	2,653	....

Year.	Gold.			Graphite.	Gypsum.		Hydrochloric Acid.
	Ore.	Bullion. (e)	Specie. (e)		Crude.	Calcined.	
1900	1	$120,988	$11,582,571	18,995	502	1,723	1,659
1901	0	42,427	6,880,888	14,900	461	1,206	1,632
1902	....	22,939	13,485,087	16,771	550	1,041	791
1903	3	10,150	11,052,944	17,302	342	1,510	3,530
1904	64	5,278	9,649,605	17,430	392	1,510	3,722
1905	1,059	9,338	10,995,089	18,535	363	1,652	4,085
1906	936	88,264	8,015,967	16,871	1,970	686	2,942
1907 (f)	996	1,234,291	13,061,517	21,704	3,841	801	3,708
1908	613	70,005	11,978,828	16,535	7,241	807	3,720
1909	548	3,426,539	19,470,382	18,484	3,675	809	3,263
1910	(h)	1,750,600	10,891,800	21,191	5,110	590	4,856
1911	(h)	6,909,408	15,220,358	21,204	3,689	914	5,834
1912	573	10,952,642	21,008,500	25,246	4,113	1,174	8,461
1913	102	2,092,318	13,719,496	24,492	2,544	988	8,969

Year.	Iron.				Lime.	Magnesium Chloride and Glauber Salts.	Magnesite (Calcined).
	Ore.	Pig and Old.	Manufactures.	Iron and Steel Bars, Sheets, Wire, etc.			
1900	263,421	53,426	40,344	65,019	86,273	7,321	(c)
1901	229,624	26,304	46,508	28,841	82,399	7,960	40,236
1902	241,806	42,592	30,137	45,517	81,634	5,333	53,467
1903	252,520	60,237	40,807	63,031	95,644	2,360	69,058
1904	295,017	66,442	60,252	64,698	101,753	2,151	53,781
1905	373,077	63,780	63,828	69,672	94,751	1,272	92,359
1906(f)	234,924	43,694	73,575	50,247	87,468	4,094	87,765
1907	220,767	37,581	56,472	69,669	89,305	6,905	113,695
1908	220,357	17,494	32,110	29,227	62,938	2,622	87,049
1909	178,464	22,627	25,455	40,837	77,586	5,446	125,666
1910	144,827	96,114	73,473	100,541	391,989	6,332	182,911
1911	114,166	87,975	60,918	75,630	511,996	2,715	147,481
1912	111,436	50,328	48,147	49,907	583,812	2,212	171,196
1913	106,071	21,148	....	....	678,194	2,151	200,947

Year.	Lead.						Manganese Ore.	Millstones.	Mineral Paints.	Nickel and Cobalt Ores.
	Ore.	Dross.	Litharge.	Metal and Alloys.	Red and Yellow.	White.				
1900	2,628	66	242	393	34	34	463	1,871	1,906	114
1901	4,143	112	179	68	32	23	398	1,971	1,947	120
1902	5,478	154	124	109	25	37	411	1,886	2,136	34
1903	8,961	147	145	152	19	25	724	2,311	1,873	12
1904	7,575	144	167	464	54	52	1,234	2,276	1,840	26
1905	7,944	342	141	957	60	39	995	2,232	2,091	16
1906(f)	4,891	223	302	602	16	52	4,170	1,763	1,367	42
1907	8,360	420	255	197	9	54	5,273	2,422	1,697	29
1908	7,107	488	312	199	22	50	2,109	3,293	2,292	*Nil.*
1909	5,711	294	343	306	125	80	787	3,849	2,577	*Nil.*
1910	6,163	322	160	418	44	510	285	3,970	3,542	13
1911	5,493	154	768	670	24	35	588	3,513	3,426	1
1912	8,618	......	28	548	19	82	534	3,530	4,272	0.3
1913	2,828	......	36	1,060	3	32	550	3,083	3,831	4.0

Year.	Nitric Acid.	Ozokerite.	Peat and Peat Coke.	Petroleum. (*d*)	Benzine.	Paraffin.	Potash.	Potassium Chloride.	Pyrite.	Sulphur.
1900....	519	5,162	5,607	33,032	18,361	26	7,792	879	17,162	1,285
1901....	632	2,717	4,558	19,804	17,021	14	4,234	909	16,491	1,225
1902....	769	2,285	4,927	40,683	13,884	24	3,229	772	9,547	1,136
1903....	908	2,258	3,638	74,454	14,000	1,153	3,409	802	10,857	1,123
1904....	858	2,093	3,980	122,419	13,706	5,992	4,604	445	9,891	988
1905....	1,377	1,614	3,746	200,736	8,187	8,996	5,511	1,048	9,168	859
1906(*f*)	1,303	2,034	2,517	198,325	13,472	9,996	3,814	1,005	7,208	760
1907....	754	1,813	4,001	212,527	12,638	14,758	5,864	1,280	5,646	784
1908....	882	1,648	4,416	351,262	25,599	28,808	4,697	776	6,286	998
1909....	745	2,321	3,395	470,085	32,532	38,043	5,667	793	4,975	1,295
1910....	1,121	2,585	1,963	271,467	39,452	44,432	5,271	957	4,565	658
1911....	1,047	1,859	2,869	220,499	41,923	38,058	4,801	943	1,190	534
1912....	1,251	2,525	1,421	338,271	68,698	51,694	4,456	855	5,041	1,048
1913....	1,373	2,275	1,155	245,184	49,773	43,102	7,460	1,370	3,885	312

Year.	Sulphuric Acid.	Tin.			Whetstones.	Zinc.				
		Ingot and Alloys.	Bars, Plates, Sheets, etc.	Dross.		Ore.	Metallic and Alloys.	Sheets, etc.	White.	Dross.
1900...	12,693	153	102	208	2,270	20,379	1,088	502	1,719	149
1901...	10,373	162	109	257	2,359	23,150	1,374	813	2,720	167
1902...	9,451	193	128	188	2,852	24,519	2,002	1,127	3,113	237
1903...	8,369	292	111	158	2,569	15,108	4,420	729	3,446	267
1904...	9,101	126	102	123	2,159	17,314	4,606	532	3,666	158
1905...	12,823	197	94	78	2,355	19,602	5,023	498	3,861	113
1906(*f*)	10,493	221	62	83	1,541	15,933	4,578	323	3,504	4,285
1907...	15,190	333	84	160	1,900	19,516	4,608	585	4,873	4,873
1908...	13,581	257	49	172	2,009	19,233	6,604	880	4,131	4,131
1909...	11,232	558	82	59	1,677	19,970	7,031	867	5,078	5,078
1910...	12,016	509	58	70	2,411	22,397	8,720	303	4,968	(*g*)
1911...	12,111	759	77	59	1,769	16,744	710	411	4,639	(*g*)
1912...	16,216	(*i*)1,038	42	......	1,414	14,539	(*i*)10,356	2,483	5,890	......
1913...	14,902	1,061	32	......	1,358	16,376	13,174	1,383	5,514	......

(*a*) From *Statistik des Auswaertigen Handels des Oesterreichisch-Ungarischen Zollgebiets.* (*b*) Includes artificial barium sulphate. (*c*) Previous to 1901, magnesite was included with other minerals not elsewhere specified. (*d*) From 1895 to 1898, inclusive, includes crude and refined petroleum; from 1899 to 1905, inclusive, lubricating oil is also included. (*e*) Where gold or silver values are reported, 1 crown = $0.203. (*f*) Last 10 months only. (*g*) Not reported. (*h*) Values in gold, $40,200 and $38,760. (*i*) Includes dross.

BELGIUM

Figures in full-faced type are either provisional figures or estimates

MINERAL, METALLURGICAL AND QUARRY PRODUCTION OF BELGIUM (a)

(In metric tons except where otherwise noted)

Year.	Barytes.	Chalk-marl. *Cubic Meters.*	Coal.		Coke.	Flint. *Cubic Meters.*	Iron Ore.
			Bituminous.	Briquets.		For Earthenware.	
1900....	38,800	3,228,205	23,462,817	1,395,910	2,434,678	25,700	247,890
1901....	22,800	1,497,250	22,213,410	1,587,800	1,847,730	17,700	218,780
1902....	33,000	1,626,670	22,877,470	1,616,520	2,102,650	17,430	166,480
1903....	21,000	1,580,330	23,796,680	1,686,415	2,428,020	16,250	184,400
1904....	60,000	1,645,655	(e)22,761,430	1,735,480	2,496,340	18,070	206,730
1905....	26,000	1,493,745	21,775,280	1,711,920	2,526,690	12,800	176,620
1906....	22,365	1,521,660	23,569,860	1,887,090	2,712,760	14,900	232,570
1907....	23,000	1,537,210	23,705,190	2,040,670	2,771,920	15,050	316,250
1908....	25,070	1,441,005	23,557,900	2,421,210	2,632,890	15,430	188,780
1909....	31,400	1,445,015	23,517,550	2,707,390	2,972,920	15,280	199,710
1910 ...	4,900	1,546,750	23,916,560	2,651,190	3,110,820	16,400	122,960
1911....	25,200	1,667,125	23,053,540	2,778,620	3,160,950	10,950	150,500
1912....	32,400	1,745,070	22,972,140	2,690,510	3,175,500	5,930	167,370
1913 ...	12,000	1,687,085	**22,845,310**	**2,608,640**	**3,447,310**	16,690	150,450

Year.	Iron, Crude.					Iron and Steel.			
	Foundry Pig.	Forge Pig.	Bessemer Pig.	Basic Pig.	Total Pig.	Ingots of Steel.	Merchant Bars.	Beams & Special Bars.	Tires.
1900....	88,335	305,344	176,557	447,271	1,018,561	655,199	....	....	11,934
1901....	86,170	178,250	166,820	332,940	764,180	515,780	334,910	186,200	12,380
1902....	104,540	254,710	199,170	510,630	1,069,050	769,040	380,990	223,380	12,790
1903....	91,600	256,890	229,160	638,430	1,216,080	969,230	446,360	138,270	17,810
1904....	99,350	224,410	217,390	742,040	1,287,597	1,065,870	543,260	268,360	23,540
1905....	98,170	206,390	220,210	784,850	1,311,120	1,200,430	570,130	299,840	25,810
1906....	96,090	218,225	177,900	870,860	1,375,775	1,440,860	552,850	346,420	32,070
1907....	92,280	189,190	88,650	1,008,170	1,406,980	1,521,610	594,170	327,930	34,700
1908....	76,290	116,740	78,950	996,870	1,270,050	1,249,620	544,810	241,060	29,000
1909....	91,040	127,080	56,430	1,340,060	1,616,370	1,580,350	628,740	291,260	33,960
1910....	82,410	115,760	55,650	1,596,970	1,852,090	1,892,160	672,730	340,850	31,860
1911....	52,970	102,690	46,240	1,836,720	2,046,280	2,128,170	711,220	380,160	35,450
1912....	94,810	66,940	44,250	2,093,480	2,301,290	2,442,420	609,930	390,340	40,320
1913....	93,830	66,370	32,260	2,291,390	2,484,690	3,104,780	855,547	213,940	175,210

Year.	Iron and Steel.				Lead.		Manganese Ore.
	Rails.	Plates.	Sheets.	Total Wrought and Steel.	Ore.	Pig. (a)	
1900	134,428	....	....	926,752	230	16,365	10,820
1901	132,260	95,190	55,300	870,230	220	61,900	8,510
1902	(c)268,220	101,280	67,350	1,106,950	164	73,357	14,440
1903	(c)351,540	113,830	74,080	1,376,630	90	68,700	6,100
1904	(c)266,900	126,960	79,040	1,378,750	91	(f)23,470	485
1905	241,640	167,240	76,510	1,469,020	126	22,885	*Nil.*
1906	274,920	166,970	84,150	1,522,995	121	23,765	120
1907	314,760	148,690	82,420	1,575,110	210	27,450	2,100
1908	(c)191,370	135,390	93,790	1,296,050	195	35,650	7,130
1909	214,000	170,750	112,160	1,569,560	150	40,306	6,270
1910	347,890	177,110	122,830	1,834,050	162	40,715	*Nil.*
1911	337,520	211,410	130,250	1,945,220	82	44,308	*Nil.*
1912	339,060	251,380	119,390	1,903,270	107	54,940	*Nil.*
1913	341,870	241,200	137,570	2,224,057	**132**	**35,750**	*Nil.*

Year.	Mineral Paints.	Phosphate of Lime.	Pyrite.	Slate. *Pieces.*	Silver. *Kg.*	Zinc.			
	Ochers.					Ore (Blende)	Ore (Calamine).	Spelter.	Sheets.
1899	(b) 300	(b)190,090	283	44,167,000	134,854	5,736	3,730	122,843	34,289
1900	(b) 300	(b)215,670	400	43,941,000	146,548	5,715	3,000	119,317	38,825
1901	2,100	222,520	560	39,030,000	169,450	4,445	2,200	127,170	37,380
1902	200	135,850	760	37,120,000	212,922	3,568	284	124,780	37,070
1903	200	184,120	720	38,953,000	232,740	3,565	65	131,740	42,280
1904	450	202,480	1,075	41,240,000	252,920	3,698	4	137,323	41,490
1905	300	193,305	976	41,435,000	201,935	3,929	*Nil.*	142,555	45,320
1906	250	152,140	908	43,801,000	173,535	3,858	*Nil.*	148,035	44,525
1907	200	181,230	397	40,102,000	178,020	3,485	5	152,370	45,330
1908	....	198,030	357	41,180,000	228,000	2,099	3	161,940	43,410
1909	700	205,260	214	41,630,000	271,270	1,229	*Nil.*	174,490	44,850
1910	600	202,880	214	36,440,000	264,655	1,434	*Nil.*	181,745	47,970
1911	540	196,780	122	37,620,000	252,720	836	*Nil.*	198,230	48,450
1912	650	203,110	148	29,600,000	279,960	1,167	*Nil.*	205,940	49,120
1913	600	219,420	**268**	27,390,000	253,940	**1,100**	*Nil.*	204,225	51,490

(a) From *Statistique des Industries Extractives et Metallurgiques et des Appareils à vapeur en Belgique.* (b) Cubic meters. (c) Includes beams. (e) Net production from this year on. (f) Domestic lead only, beginning with this year.

CANADA

The statistics of mineral production in the Dominion of Canada as reported by the Geological Survey are summarized in the following tables. The statement of imports and exports for 1907 is for the nine months ending March 31, in consequence of a change in the law whereby the fiscal year was changed from June 30:

MINERAL PRODUCTION OF THE DOMINION OF CANADA (*a*)
(In metric tons or dollars)

Year.	Arsenic.	Asbestos and Asbestic.	Barytes.	Cement. *Barrels.* (*j*)		Chromite.	Coal.	Cobalt and Oxide.	Coke. (*k*)
				Natural Rock.	Portland.				
1903....	725	37,902	1,055	92,252	627,741	3,509	6,933,107	.....	509,115
1904....	(*d*) 66	44,131	1,253	51,555	771,650	5,511	6,812,834	.....	493,107
1905....	*Nil.*	61,928	3,049	14,184	1,346,547	7,781	7,961,397	.....	622,154
1906....	*Nil.*	72,025	3,628	8,610	2,139,164	7,936	9,033,973	.....	(*b*)
1907....	317	82,117	1,829	5,775	2,368,593	6,527	9,533,442	.....	(*b*)
1908....	634	82,448	3,911	1,044	2,665,289	7,341	9,857,754	841	784,788
1909....	1,024	79,197	(*b*)	*Nil*	4,067,709	2,240	9,526,938	(*i*)	782,016
1910....	1,362	92,800	(*b*)	*Nil*	4,753,975	276	11,711,000	(*i*)	818,450
1911....	1,902	115,136	45	*Nil*	5,692,915	143	10,243,528	(*i*)	848,280
1912....	1,855	123,679	421	*Nil*	7,132,732	(*b*)	13,168,941	(*i*)	1,275,829
1913....	1,535	146,169	581	*Nil*	8,658,805	(*b*)	13,622,070	(*i*)	1,376,646
1914....	1,576	106,686	555	*Nil*	7,172,480	123	12,336,088	(*i*)	921,241
1915....	2,174	124,123	499	*Nil*	5,681,032	11,196	12,035,843	229	1,089,335
1916....	1,983	140,177	1,241	*Nil*	5,359,000	24,522	13,119,624	382	1,314,335

Year.	Copper. (In Ore, etc.)	Corundum.	Feldspar.	Gold. (*c*)	Graphite.	Grindstones.	Gypsum.	Iron Ore.	Iron, Pig. All kinds.
1903..	19,357	880	12,633	$18,843,590	660	5,023	285,242	239,715	270,182
1904..	19,497	834	10,057	16,400,000	410	4,091	309,133	317,387	275,367
1905..	21,596	1,492	10,617	14,486,833	491	4,693	395,341	263,113	475,491
1906..	25,863	2,063	14,397	12,023,932	405	5,029	378,904	269,842	550,628
1907..	26,025	1,716	11,414	8,264,765	525	4,881	431,286	283,820	590,444
1908..	28,895	988	7,144	9,842,105	227	3,285	309,254	215,986	572,284
1909..	23,811	1,353	11,594	9,382,230	783	3,877	429,218	(*d*) 243,167	(*g*) 686,886
1910..	25,262	1,696	14,114	10,205,835	1,263	3,604	476,496	(*d*) 235,342	(*g*) 726,471
1911..	25,250	1,336	16,074	9,781,077	1,151	4,818	458,550	190,823	(*g*) 832,376
1912..	35,314	1,778	12,461	12,648,794	1,869	4,003	524,892	107,190	(*g*) 920,636
1913..	34,926	1,068	15,235	16,598,923	1,962	4,389	577,442	196,558	(*g*) 1,024,424
1914..	34,364	507	16,388	15,925,044	1,494	3,700	463,375	54,816	(*g*) 710,675
1915..	45,717	238	13,208	18,976,218	2,390	2,341	430,752	81,403	(*g*) 828,977
1916..	54,327	61	17,387	19,162,025	3,602	3,019	309,916	127,560	1,060,787

Year.	Iron and Steel, Rolled.	Lead. (In ore, etc.)	Manganese Ore.	Mica.	Mineral Paints. (Ochers)	Natural Gas.	Nickel. (In ore, etc.)	Petroleum, Crude. *Barrels.* (*e*)
1903....	131,588	8,226	83	$177,857	5,683	$202,210	5,671	486,637
1904....	(*b*)	17,241	(*d*) 112	152,919	3,562	247,370	4,786	552,575
1905....	(*b*)	25,391	(*d*) 20	168,170	4,632	314,249	8,565	634,095
1906....	(*b*)	24,580	(*d*) 84	(*d*) 581,043	6,201	528,868	9,745	569,753
1907....	(*b*)	21,570	....	333,022	7,115	748,541	9,610	788,872
1908....	(*h*) 534,117	19,593	....	139,871	4,305	1,012,660	8,685	527,987
1909....	(*h*) 684,670	20,801	....	147,782	3,573	1,207,029	11,922	420,755
1910....	(*h*) 745,963	14,963	....	190,385	4,365	1,346,471	16,905	315,895
1911 ...	(*h*) 800,722	10,617	5	128,667	3,285	1,917,673	15,457	291,092
1912....	868,617	16,227	68	143,976	6,945	2,362,700	20,346	243,336
1913....	....	17,089	0	194,304	5,432	3,309,381	22,539	228,080
1914....	....	16,487	25	109,061	5,345	3,484,727	20,652	214,805
1915....	....	21,009	182	91,905	5,668	3,706,035	30,985	215,464
1916....	....	18,866	888	122,541	7,993	3,924,632	37,629	198,123

Year.	Phosphate. (Apatite.)	Pyrite.	Salt.	Silver. *Kg.* (In ore, etc.)	Soapstone and Talc.
1903	1,205	30,822	56,644	99,489	898
1904	832	29,980	62,411	115,666	762
1905	1,180	29,713	41,159	185,839	454
1906	(*b*)	35,927	69,283	266,521	1,119
1907	680	35,494	65,936	390,359	1,391
1908	1,447	42,934	72,537	687,504	976
1909	905	58,645	76,237	856,263	3,945
1910	1,341	48,871	76,286	1,022,350	6,450
1911	563	74,978	83,065	1,012,586	6,621
1912	149	73,976	86,248	993,952	7,504
1913	349	143,882	91,457	990,538	11,115
1914	866	204,125	97,126	856,741	9,807
1915	197	259,494	108,773	828,067	10,782
1916	184	280,698	112,523	798,383	9,663

(*a*) From *Reports Compiled by the Geological Survey of Canada.* (*b*) Not reported. (*c*) Gold values are calculated at the rate of $20.67 per oz. (*d*) Export. (*e*) One barrel contains 35 imp. gal. (*g*) From Canadian ore, 149,444 short tons in 1909, 104,906 tons in 1910, 42,186 tons in 1911, 36,355 tons in 1912, 73,508 tons in 1913, 95,744 in 1914 and 158,595 short tons in 1915. (*h*) Steel ingots and castings. (*i*) 1909, $94,609; 1910, $51,986; 1911, $221,790; $320,244 in 1912, $695,855 in 1913 $678,619 in 1914, for oxides of cobalt and nickel; values received. (*j*) Bbl. of 350 lb. each, sold or shipped. (*k*) Including that from foreign coal.

MINERAL IMPORTS OF THE DOMINION OF CANADA (*a*)

(In metric tons or dollars)

Year. (*b*)	Aluminium.		Antimony. (*c*)	Arsenic.	Asbestos. (*d*)	Asphalt.	Cement.
	Manufactures. (*m*)	Ingots, Sheets, etc.					
1904	$16,065	$101,427	190	188	$83,827	7,093	$1,014,713
1905	28,418	154,569	85	122	116,836	5,096	1,263,828
1906	23,565	168,405	183	202	138,000	7,178	1,003,022
1907(*o*)	20,656	218,399	146	158	127,509	11,929	540,006
1908(*r*)	37,197	131,762	220	228	191,204	14,113	865,275
1909(*r*)	30,076	167,019	201	58	181,710	15,979	473,211
1910(*r*)	42,493	424,006	232	12	198,756	19,661	159,040
1911(*r*)	83,638	782,254	257	115	254,331	23,248	(*t*)494,446
1912(*r*)	119,070	487,490	233	159	349,655	28,291	(*t*)936,425
1913(*r*)	126,531	403,700	400	259	497,160	47,353	(*t*)1,955,177
1914(*r*)	151,261	730,012	322	127	474,499	48,564	(*t*)352,134
1915(*r*)	87,242	672,527	733	8	226,515	38,175	(*t*)132,492
1916(*r*)	85,574	700,365	595	146	191,886	38,029	45,295
1917(*r*)	197,950	349,455	278	125	394,540	29,246	29,719

Year.	Coal.		Coke.	Copper. Ingots, Pig, and Scrap.	Copper Sulphate.	Gold and Silver. Coin and Bullion. (*g*)
	Anthracite. (*f*)	Bituminous. (*f*)				
1904	2,064,444	4,230,436	200,590	960	795	$7,874,313
1905	2,361,952	4,377,667	337,035	882	934	10,308,435
1906	1,996,183	5,003,029	435,561	1,191	844	7,078,603
1907(*o*)	1,260,723	4,022,843	363,286	1,186	897	7,029,047
1908(*r*)	2,803,681	7,681,464	561,677	1,638	1,161	6,548,661
1909(*r*)	2,775,680	6,526,797	423,013	1,239	963	9,988,442
1910(*r*)	2,860,196	10,382,156	636,888	2,329	859	6,017,589
1911(*r*)	3,144,130	7,785,259	692,292	2,279	772	10,206,210
1912(*r*)	3,736,169	9,526,138	582,331	2,514	930	26,033,881
1913(*r*)	3,844,062	10,034,383	644,207	2,581	1,153	5,527,979
1914(*r*)	3,979,674	12,479,959	643,693	2,511	606	15,235,317
1915(*r*)	3,971,968	8,279,570	460,381	2,053	335	131,993,031
1916(*r*)	4,429,143	9,631,101	693,607	1,689	862	34,260,202
1917(*r*)	4,144,488	11,730,145	686,389	2,308	921	28,381,120

Year.	Graphite.		Gypsum.		Iron and Steel.		
	Crude.	Manufactures.	Crude and Ground.	Plaster of Paris.	Pig and Scrap.	Slabs, Blooms Bars, etc.	Alloys of Iron.
1905..........	$2,499	$75,288	2,972	3,595	90,698	14,420	11,738
1906..........	2,791	86,028	5,743	6,579	112,937	29,520	13,626
1907(o)......	3,176	57,430	8,334	9,730	137,654	17,369	17,785
1908(r).......	3,030	78,380	8,519	6,955	190,994	35,534	16,139
1909(r)......	1,408	75,608	9,359	7,712	62,967	43,263	13,571
1910(r)......	5,223	95,900	3,618	19,095	159,515	97,036	14,471
1911 (r)......	4,300	97,057	11,443	19,664	266,269	139,060	15,773
1912(r).......	6,163	84,240	2,130	9,313	214,046	80,250	16,578
1913(r).......	6,105	89,719	8,800	28,975	306,927	77,176	20,837
1914(r)......	3,639	71,340	4,877	15,084	251,730	145,731	26,256
1915(r)......	1,464	43,313	3 236	5,769	69,261	50,086	2,534
1916(r)......	3,620	48,614	1,658	2,222	54,936	122,786	12,761
1917(r)......	3,008	102,960	2,741	3,877	69,811	49,646	12,069

Year.	Kainite.	Lead.				Lime.		Mineral Paints (Ochers).
		Pig and Scrap.	Bars and Sheets.	Litharge.	Pigments and Zinc White.	Burned. *Barrels.*	Chloride.	
1905...	306	2,589	800	811	9,695	98,676	2,507	1,417
1906...	306	3,751	730	461	6,947	134,334	2,645	809
1907(o)	511	3,811	622	513	2,215	88,919	2,302	570
1908(r)	743	2,902	782	864	5,743	129,379	3,421	788
1909(r)	562	2,273	623	550	3,998	153,934	2,697	546
1910(r)	687	5,755	580	915	4,433	191,527	4,554	914
1911 (r)	339	5,292	707	750	5,312	176,730	4,745	1,169
1912 (r)	262	10,934	1,356	745	4,921	230,013	5,584	1,358
1913 (r)	19	10,980	918	1,197	6,627	360,242	5,248	1,649
1914 (r)	180	5,078	654	512	7,547	....	6,264	1,605
1915 (r)	350	7,539	358	479	5,350	....	2,446	1,282
1916 (r)	44	22,928	477	1,043	6,090	....	4,973	1,162
1917 (r)	174	5,473	405	1,147	7,274	....	3,670	1,774

Year.	Nickel.	Petroleum Products.		Platinum.	Potassium Salts.		Quicksilver.
		Illuminating Oil, etc., Crude or Refined. *Gallons.*	Paraffin Wax and Candles.		Except Saltpeter.	Saltpeter.	
1905........	$19,076	13,229,855	98	$61,719	945	1,048	47
1906........	15,976	10,981,611	375	54,494	1,317	1,141	68
1907(o).....	19,461	8,066,403	189	113,967	1,074	638	44
1908(r).....	....	8,844,129	102	63,582	3,396	2,653	81
1909(r).....	(s)67,107	13,095,593	103	47,371	1,570	925	42
1910(r).....	(s)98,238	(u)48,384,763	253	80,180	2,497	665	129
1911 (r).....	137,114	(u)66,119,105	931	136,823	3,152	1,490	59
1912(r).....	135,227	88,916,283	808	190,770	3,734	1,049	49
1913(r).....	194,079	164,013,894	892	221,300	5,643	835	67
1914(r).....	144,343	202,540,731	717	121,336	8,057	776	115
1915(r).....	172,037	211,900,141	623	65,008	4,139	1,034	67
1916(r).....	239,495	213,670,889	549	100,415	1,706	850	83
1917(r).....	402,831	268,040,441	536	77,907	402	277	39

Year.	Sal-Ammoniac.	Salt.	Silex.	Sodium Salts, Except Chloride.	Sulphur.	Tin and Tin-ware.	Zinc.
1905 ...	143	97,723	405	26,219	10,633	$2,791,757	1,721
1906 ...	209	99,788	338	30,401	19,512	3,105,876	3,383
1907(o).	130	73,156	542	25,068	11,725	2,473,572	2,761
1908(r).	172	105,286	1,131	39,154	23,494	1,619,647	2,521
1909(r).	162	119,660	417	33,787	19,981	2,984,065	2,993
1910(r).	303	121,473	582	47,913	19,484	3,512,615	(v)7,606
1911(r).	346	111,174	468	62,969	22,935	4,235,848	(v)6,069
1912(r).	377	119,114	337	74,016	20,430	3,710,102	7,217
1913(r).	544	100,494	658	98,561	32,984	3,055,943	9,397
1914(r).	356	132,777	755	100,701	27,093	6,350,610	7,402
1915(r).	430	121,683	582	78,894	39,412	4,783,108	7,230
1916(r).	420	125,804	402	96,321	34,411	5,312,847	7,357
1917(r).	351	143,778	1,608	117,854	76,179	10,508,012	7,251

EXPORTS OF DOMESTIC MINERAL PRODUCE FROM THE DOMINION OF CANADA (a)
(In metric tons or dollars)

Year. (b)	Antimony Ore.	Asbestos.	Chromite.	Coal.	Coke.	Copper. (e)
1905........	340	37,320	3,702	1,465,809	116,387	17,431
1906........	388	40,367	1,640	1,651,203	50,004	20,082
1907(o)......	832	37,194	604	1,165,809	44,669	11,845
1908(r)......	693	53,543	1,585	1,702,673	50,343	25,824
1909(r)......	1	54,188	3,707	1,548,468	70,024	24,642
1910(r)......	33	58,083	1,052	1,822,398	44,343	26,107
1911(r).....	222	63,348	14	2,100,309	54,380	24,950
1912(r).....	1	69,233	....	1,436,798	13,677	25,595
1913(r).....	....	83,299	....	1,920,809	56,271	36,717
1914(r).....	....	96,159	....	1,360,029	66,512	37,772
1915(r).....	306	67,968	72	1,372,431	47,978	28,438
1916(r).....	970	80,611	10,649	1,788,679	39,737	52,995
1917(r).....	609	87,086	11,944	1,722,941	35,290	61,265

Year.	Gold. Quartz, Dust, etc.	Graphite.	Grindstones.	Gypsum, Crude.	Iron Ore.	Lead. (p)
1905......	$15,208,380	201	$27,985	290,574	204,091	23,094
1906......	12,991,916	180	15,793	367,203	134,270	6,158
1907(o) ...	7,226,954	3	33,929	249,780	31,011	8,330
1908(r) ...	8,817,041	167	28,726	340,235	23,863	12,650
1909(r) ...	7,392,610	396	18,019	239,139	3,568	5,459
1910(r) ...	6,110,473	1,164	13,754	304,736	28,608	8,395
1911(r) ...	5,344,465	362	23,914	325,928	95,080	1,451
1912(r) ...	7,211,438	1,395	30,513	324,324	34,162	52
1913(r) ...	11,231,476	1,572	27,375	344,183	123,004	93
1914(r) ...	13,326,755	1,367	54,584	359,287	103,126	125
1915(r) ...	15,406,510	451	45,889	292,800	198,412	328
1916(r) ...	16,870,394	366	19,971	348,923	75,212	1,406
1917(r) ...	19,671,026	180	36,646	205,575	155,773	7,924

Year.	Manganese Ore.	Mica.	Nickel in Ore, Matte, etc.	Petroleum, Crude and Refined.	Pyrites.	Salt. *Bushels.*	Silver (in Ore, Matte, etc). *Kg.*
1905	84	461	5,431	6,441	20,473	5,663	112,076
1906	15	603	10,866	1,741	18,398	23,168	203,323
1907(*o*)...	84	631	7,355	(*q*)3,167	20,148	5,113	274,178
1908(*r*)...	1	409	8,596	(*q*)3,389	17,835	35,543	515,161
1909(*r*)...	3	243	8,895	(*q*)195	23,087	(*w*)3,040	733,248
1910(*r*)...	5	397	13,891	(*q*)9,093	24,439	(*w*)6,088	932,098
1911(*r*)...	2	370	15,771	(*q*)1,493	32,396	(*w*)6,625	1,049,153
1912(*r*)...	12	348	15,073	38,663	25,279	109,963	960,586
1913(*r*)..	7	415	21,849	152,746	3,109	60,536	1,096,835
1914(*r*)...	....	321	22,949	(*q*)25,443	42,006	(*w*)6,165	1,143,337
1915(*r*)...	82	387	20,604	(*q*)18,376	87,021	(*w*)15,865	788,656
1916(*r*)...	489	392	31,912	(*q*)512,443	131,598	9,227	864,527
1917(*r*) .	581	608	37,476	(*q*)238,875	137,038	10,082	741,657

(*a*) From Tables of the *Trade and Navigation of the Dominion of Canada.* (*b*) Fiscal year ending June 30. (*c*) Includes regulus and salts of antimony. (*d*) Asbestos in any form except crude, and all manufactures of. (*e*) Includes copper in ore, matte, regulus, etc. (*f*) Includes coal dust. (*g*) Coin, gold and silver, except U. S. silver coin. (*h*) Includes black lead and crucibles (clay or graphite). (*i*) Includes Canadian lead ore refined in the United States. (*m*) Unclassified. (*n*) Includes chromic iron ore. (*o*) Returns for the 9 months of the fiscal year ending March 31. (*p*) Includes lead contained in ore, etc. (*q*) Gallons. (*r*) Fiscal year ending March 31. (*s*) Includes silver-nickel and German silver. (*t*) Weight, 64,176 tons; 46,821, 247,940, 35,431, and 14,370 net tons. (*u*) Includes all oils. (*v*) Not including manufactures. (*w*) Using 60 lb. per bushel.

CHINA

The official statistics of mineral imports and exports are summarized in the following table:

MINERAL IMPORTS OF CHINA (a)

(In metric tons)

Year.	Brass and Yellow Alloys.	Copper.	Lead.	Nickel.	Petroleum. *Gal.*	Quick-silver.	Tin.	Tin-plate.	Zinc.	
									Spelter.	Sheet, etc.
1911...	1,244	4,408	8,138	39	235,898,240	49	1,994	21,676	81	769
1912...	970	7,368	6,187	56	197,902,362	49	2,548	21,036	443	861
1913...	1,628	12,144	6,511	109	183,984,052	40	3,566	21,983	529	1,971
1914...	1,646	17,461	7,093	61	225 464,201	21	3,922	25,369	509	851
1915...	802	2,131	5,681	66	....	11	2,503	24,066	17	61

MINERAL EXPORTS OF CHINA (a)

(In metric tons)

Year.	Antimony.		Iron.		Lead.		Quick-silver.	Tin.	Zinc.	
	Ore.	Metal.(b)	Ore.	Pig and Mnfd.	Ore.	Pig.			Ore.	Spelter.
1911.....	6,812	6,986	112,295	70,906	5,410	11	18.5	6,056	4,599	710
1912.....	2,054	13,531	355,538	12,604	4,276	20	4.3	8,786	7,170	760
1913.....	4,351	13,032	274,064	64,811	4,066	42	2.1	8,390	9,550	908
1914.....	4,972	19,645	299,515	60,068	3,722	235	59.7	7,215	7,374	310
1915.....	1,873	23,357	308,973	96,537	57	687	40.7	8,006	8,541	2,328

(a) From annual reports of the Imperial Chinese Maritime Customs. (b) Regulus and refined.

FRANCE

In the following tables are given the statistics of mineral and metal production in France and the French colonies—Algeria, New Caledonia and Tunis—together with the foreign commerce of France in mineral and metal products. Figures in full-faced type are either provisional figures or estimates.

MINERAL AND METALLURGICAL PRODUCTION OF FRANCE (*a*)
(In metric tons)

Year.	Aluminium.	Antimony.		Arsenic Ore.	Asphaltum.	Barytes.	Bauxite.	Bitumen. (*c*)	Cement.
		Ore.	Metal.						
1901.......	1,200	9,867	1,786	7,491	20,391	4,145	76,620	249,655	1,127,206
1902.......	1,355	9,715	1,725	5,372	......	4,323	96,900	258,295	962,930
1903.......	1,570	12,380	2,748	6,658	......	5,731	133,890	243,295	898,393
1904.......	1,650	9,065	2,116	3,117	22,000	6,944	75,640	227,177	903,632
1905.......	1,905	12,543	2,396	3,627	20,000	5,504	103,207	188,403	922,531
1906.......	3,396	18,567	3,433	6,534	38,231	11,680	117,781	196,375	1,257,861
1907.......	4,700	24,000	3,950	7,900	33,000	11,150	158,000	177,000	1,253,546
1908.......	4,681	26,026	3,850	2,381	41,000	16,277	170,679	171,158	1,359,658
1909.......	6,092	28,105	5,444	2,141	44,800	14,111	130,149	169,000	1,374,574
1910......	6,425	28,130	4,640	8,045	38,500	11,632	196,056	169,769	1,521,131
1911.......	7,400	29,267	4,775	19,000	39,000	10,064	254,831	170,000	1,795,000
1912.......	10,200	11,018	(*i*)5,406	81,880	31,535	13,620	258,929	312,000	1,924,277
1913.......	13,483	17,036	6,390	70,613	30,892	12,236	309,294	324,601	1,930,066

Year.	Coal.	Lignite.	Peat.	Copper.		Gold.	Gypsum.	
				Ore.	Metal.		Crude.	Calcined.
1902.....	29,365,047	632,423	109,941	828	6,300	(*b*)	219,487	1,572,687
1903.....	34,217,661	688,757	100,348	10,892	6,921	(*b*)	162,766	1,468,830
1904.....	33,502,394	665,572	95,716	2,756	6,900	(*b*)	106,173	1,481,303
1905.....	35,218,000	709,000	98,500	5,068	7,576	$235,447	78,832	1,299,313
1906.....	33,458,000	738,000	92,469	2,547	5,770	511,665	79,568	1,297,861
1907.....	35,989,000	765,000	90,952	2,400	7,800	847,290	87,370	1,316,567
1908.....	36,633,000	751,000	79,759	766	7,935	960,666	92,898	1,326,131
1909.....	37,115,500	724,500	78,600	458	7,823	1,147,400	76,057	1,263,692
1910.....	37,634,893	715,000	48,415	222	12,933	(*h*) 1,706,580	64,181	1,533,298
1911.....	38,521,000	709,000	58,521	35	13,200	(*h*) 1,463,519	59,648	1,640,698
1912.....	41,145,000	751,000	43,000	242	11,907	**1,993,620**	25,900	1,700,000
1913.....	40,050,888	793,330	44,878	521	11,968	153,009	66,218	....

Year.	Iron.				Lead.		Lime.	Manganese Ore.	Millstones.
	Ore.	Pig	Wrought Iron.	Wrought Steel.	Ore. (*d*)	Pig. (*e*)			
1902.	5,003,782	2,405,000	639,600	1,245,800	22,634	19,000	4,796,807	12,536	34,504
1903.	6,219,541	2,840,517	598,910	1,305,709	23,080	23,258	4,727,543	11,583	35,031
1904.	7,022,841	2,999,787	554,632	1,482,708	14,173	18,800	4,583,522	11,254	37,409
1905.	7,395,409	3,077,000	670,000	1,442,000	12,118	24,100	3,694,725	6,751	33,468
1906.	8,481,423	3,314,100	747,900	1,683,500	11,795	25,614	3,869,772	11,189	32,407
1907.	10,008,000	3,590,000	579,900	1,860,000	18,000	24,800	2,438,409	18,200	30,480
1908.	10,057,145	3,400,700	560,200	1,851,900	13,403	26,112	2,535,833	15,865	30,522
1909.	11,890,000	3,573,848	558,000	2,040,364	13,794	26,927	2,211,653	9,378	30,503
1910.	14,605,542	4,038,000	526,000	2,324,000	14,536	20,226	2,110,540	7,925	32,461
1911.	16,639,000	4,470,100	518,000	3,812,665	14,098	23,635	3,291,000	6,036	34,255
1912.	19,160,000	4,939,194	525,000	4,403,688	13,953	31,086	3,807,596	5,576	33,751
1913.	21,918,000	5,207,307	405,972	4,686,866	17,081	28,817	2,838,392	7,732	29,994

Year.	Mineral Paints (Ochers)	Nickel.	Phosphate Rock.	Pyrite.	Salt.	Silver. *Kg.*	Sulphur Ore. (*g*)	Zinc. Ore.	Zinc. Metal.
1901....	35,704	1,800	535,676	307,447	910,000	......	7,000	61,539	37,600
1902....	34,770	1,600	543,900	318,235	863,927	......	8,021	57,982	36,300
1903....	34,042	1,500	475,783	322,118	967,531	......	7,375	66,922	37,416
1904....	34,945	1,500	423,521	271,544	1,153,754	......	5,447	52,842	41,600
1905....	37,800	1,800	476,720	267,114	1,162,100	......	4,637	62,150	43,200
1906....	35,550	1,750	469,408	265,261	1,388,500	50,058	2,713	53,466	46,536
1907....	32,856	1,500	432,237	283,000	1,324,000	47,009	2,000	44,000	47,900
1908....	33,060	1,800	485,607	284,717	1,173,000	61,184	2,189	52,611	47,880
1909....	33,540	1,600	397,908	273,221	1,113,000	63,671	2,900	96,903	49,956
1910....	32,870	2,100	333,506	250,432	1,051,427	52,957	2,641	50,624	52,598
1911....	34,542	1,180	312,204	277,900	1,339,000	47,277	1,200	43,761	57,110
1912....	41,810	1,725	313,151	282,202	1,099,000	63,736	1,000	45,929	62,651
1913....	56,240	1,500	298,859	311,167	1,281,978	31,268	659	46,577	67,890

(*a*) From *Statistique de l'Industrie Minérale.* (*b*) Not reported. (*c*) Includes pure bitumen, bituminous schist and sand, and asphaltic limestone. (*d*) Argentiferous lead ore. (*e*) Lead produced from native ores only. (*g*) Sulphur and limestone impregnated with sulphur. (*h*) From ores. (*i*) Regulus and oxide.

MINERAL PRODUCTION OF ALGERIA (*a*)

(In metric tons)

Year.	Antimony Ore.	Copper Ore.	Gypsum. Crude.	Gypsum. Plaster.	Iron Ore.	Lead-Silver Ore.	Mercury.	Onyx.	Phosphate Rock.	Salt.	Zinc Ore.
1904...	160	1,804	350	38,420	468,737	511	.....	121	343,317	18,563	47,192
1905...	......	1,784	.....	34,743	568,609	7,470	.....	270	334,784	26,986	67,922
1906...	50	2,786	.....	27,950	779,826	11,246	.....	216	333,531	22,615	74,351
1907...	799	16,259	.....	26,400	973,445	15,264	590	328	373,763	20,390	71,046
1908...	190	3,330	.....	25,500	943,424	10,626	1,556	300	452,060	25,215	94,398
1909...	163	67	.....	29,000	836,044	11,131	.....	200	345,385	17,817	81,852
1910 (*a*)	(*c*)4,475	112	.....	48,500	1,064,909	12,652	50	123	412,319	21,470	94,445
1911...	(*c*)7,428	4,939	.....	51,760	1,025,643	17,909	.....	198	335,059	20,431	60,895
1912...	(*c*)2,165	316	.....	54,400	1,225,625	24,516	.....	300	373,881	23,950	84,495
1913...	(*c*)582	13,164	700	50,399	1,349,000	13,953	18	168	377,934	26,969	82,256
1914...	1,947	1,090	.....	....	1,514,099	25,986	.....	...	485,552	......	81,961
1915...	9,022	*Nil.*	.....	....	818,705	15,046	.....	...	225,871	......	16,796
1916...	28,473	1,098	.....	....	938,684	23,731	32	...	380,211	......	28,973

MINERAL PRODUCTION OF NEW CALEDONIA. (*a*)

(In metric tons.)

Year.	Chrome Iron Ore.	Cobalt. Ore.	Copper Ore.	Nickel. Ore.	Year.	Chrome Iron Ore.	Cobalt Ore.	Copper Ore.	Nickel Ore.
1900.....	10,474	2,438	2	100,319	1907...	57,367	29,800	437	119,000
1901.....	17,451	3,123	6,349	132,814	1908...	25,371	2,360	(*b*) 10	108,000
1902.....	10,281	7,512	3,720	129,653	1909...	40,000	548	9,600	86,000
1903.....	21,437	8,292	10	77,360	1910...	40,000	54	8,000	99,000
1904.....	42,197	8,964	*Nil.*	98,655	1911...	35,000	*Nil.*	1,900	142,000
1905.....	51,374	7,920	*Nil.*	125,289	1912(*c*)	51,516	*Nil.*	(*d*)	74,312
1906	84,211	2,600	207	118,890	1913(*c*)	63,370	......	......	164,406

(*a*) From *Statistique de l'Industrie Minérale.* (*c*) Exports *Echo des Mines.* (*d*) Copper matte worth $101,000.

MINERAL PRODUCTION OF TUNIS (*a*)

(In metric tons)

Year.	Salt.	Lead Ore.	Phosphate of Lime.	Zinc Ore.	Year.	Salt.	Lead Ore.	Phosphate of Lime.	Zinc Ore.
1901....	16,900	8,158	172,000	17,879	1908...	149,600	37,500	1,300,500	26,500
1902....	12,600	12,892	264,930	18,400	1909...	118,400	41,600	1,300,000	24,500
1903....	18,846	12,752	352,088	21,262	1910...	199,700	(*c*) 37,000	1,334,000	(*c*) 32,500
1904....	23,600	16,800	455,197	27,200	1911...	63,700	36,100	1,592,000	(*c*) 27,900
1905....	54,900	15,200	522,000	37,100	1912...	92,000	51,300	2,050,000	37,400
1906...	62,600	14,800	796,000	32,400	1913(*b*)	94,100	52,200	2,170,500	30,300
1907...	78,200	18,600	1,069,000	22,800	1914...	......	......	1,427,000	

(*a*) From *Statistique de l'Industrie Minérale.* (*b*) From *l'Echo des Mines.*

MINERAL IMPORTS OF FRANCE (*a*) (*k*)

(In metric tons or dollars. 5 f. = $1)

Year.	Alum.	Bitumen. (*f*)	Borax.	Bromides.	Cement.	Coal and Coke.	Copper. Ore.	Copper. Ingot and Mfrs.	Copper. Sulphate.	Copper. Oxide.
1900....	23	39,598	111	10	13,612	14,601,981	9,766	61,638	22,820	84
1901....	39	28,888	128	3	16,232	13,925,623	13,383	47,035	15,313	162
1902....	36	26,053	141	3	15,720	13,137,720	17,862	54,484	22,273	111
1903....	138	27,573	312	9	21,152	14,029,687	9,796	59,126	25,428	129
1904....	370	17,178	3,113	17	21,702	13,936,475	9,942	69,183	30,856	142
1905....	63	24,606	1,736	31	21,954	13,910,523	14,252	70,101	23,805	57
1906....	105	99,336	189	93	24,974	17,848,284	11,932	64,590	15,358	97
1907....	......	31,700	......	....	24,839	18,706,000	12,063	76,282	....	......
1908....	......	48,000	......	....	31,550	18,563,000	15,300	86,985	....	......
1909....	......	54,000	......	....	46,664	19,387,000	27,400	86,143	....	......
1910....	46	36,360	8,322	17	51,905	18,145,872	23,362	93,548	11,887	427
1911....	129	32,207	3,128	12	86,457	19,740,539	24,585	104,724	17,759	151
1912....	190	39,508	3,277	20	115,286	19,878,477	19,671	112,148	16,800	134
1913....	......	....	......	....	....	....	9,653	....	....	......
1914....	......	....	......	....	....	17,637,149	....	89,140	....	......
1915....	......	....	......	....	....	19,693,599	....	126,127	....	......

Year.	Cobalt Ore.	Iron. Ore.	Iron. Pig.	Iron. Iron and Steel, Mfrs.	Iron. Sulphate.	Iron. Oxide.	Kaolin.	Lead. Ore.	Lead. Carbonate.	Lead. Pig, Scrap, and Mfrs.
1900....	....	2,119,003	(*b*)	118,152	1,589	1,022	39,842	19,772	1,739	70,857
1901....	....	1,662,875	(*b*)	77,742	45	1,001	41,972	15,430	1,789	59,051
1902....	....	1,563,334	149,755	60,697	17	1,051	41,165	13,121	2,223	58,694
1903....	....	1,832,820	61,085	119,799	36	1,207	47,534	20,172	2,040	75,416
1904....	....	1,738,514	38,521	125,709	319	1,151	50,465	25,731	2,221	76,198
1905....	....	2,151,954	121,726	150,480	709	1,330	52,603	35,103	2,306	73,938
1906....	....	2,015,550	135,252	342,411	132	1,311	44,772	43,137	2,072	67,651
1907....	1,396	1,999,000	122,102	336,337	....	....	53,447	42,342	....	53,359
1908....	1,500	1,454,000	156,618	373,624	....	....	58,909	40,700	....	70,824
1909....	400	1,202,619	154,031	354,428	....	....	59,490	38,400	....	68,332
1910....	2.6	1,318,520	168,810	378,227	2,243	1,235	62,920	28,950	3,259	64,517
1911....	0.3	1,350,794	194,225	77,000	4,454	1,511	66,500	47,340	3,095	69,791
1912....	....	1,454,190	36,637	114,100	2,800	1,466	63,783	42,499	2,919	65,449
1913....	....	....	49,612	....	....	....	61,255	39,772	....	....
1914....	....	1,044,160	57,241	....	....	....	....	....	....	41,900
1915....	....	397,348	....	....	....	....	....	....	....	51,700

Year.	Lime, Chloride of.	Manganese Ore.	Nickel.		Petroleum.	Phosphate Rock.	Platinum *Kg.*	Potassium.	
			Ore.	Metal.				Chloride.	Chromate. (*h*)
1900	1,215	120,790	17,687	299	302,482	283,921	2,398	13,524	3,293
1901	1,400	94,365	39,497	252	225,962	275,285	1,857	13,299	2,784
1902	2,130	85,629	58,374	301	148,170	302,898	2,940	10,802	2,861
1903	919	109,930	13,933	427	(*g*)476,230	343,012	3,764	12,275	2,760
1904	1,679	105,652	20,698	313	(*g*)435,730	419,720	5,650	14,734	2,618
1905	406	140,871	49,698	632	(*g*)512,727	447,738	4,023	21,819	2,619
1906	593	127,235	44,960	480	(*g*)213,462	533,213	5,708	26,523	3,024
1907	....	192,448	45,892	979	(*g*)311,000	636,549	4,373	....	....
1908(*k*)..	....	170,500	42,200	1,281	(*g*)300,000	767,424	3,955	....	....
1909(*k*)..	....	177,314	12,200	....	(*g*)300,000	645,178	5,914	....	....
1910	333	188,292	28,001	2,074	(*g*)271,500	687,675	7,795	34,974	3,009
1911	53	235,400	43,014	6,465	(*g*)375,000	740,375	9,392	39,508	2,991
1912	24	225,379	27,126	5,032	(*g*)360,000	903,490	6,236	45,174	3,178
1913	....	258,929	10,292	....	....	934,679	....	....	....
1914	....	....	....	3,174	(*g*)488,555	661,429	....	....	....
1915	....	....	....	3,892	(*g*)480,392	325,114	....	....	....

Year.	Potassium (*Cont'd*).		Pyrite.	Quicksilver.		Sal Ammoniac.	Salt.	Sodium.	
	Nitrate.	Carbonate.		Ore.	Metal.			Hydrate.	Nitrate.
1901	757	2,520	205,617	23	205	9,268	32,347	869	10,526,400
1902	1,547	1,539	170,783	24	224	15,446	32,505	643	9,372,600
1903	1,530	3,019	205,322	20	220	12,462	48,556	781	10,810,775
1904	2,117	3,781	230,097	22	208	13,744	46,232	1,068	9,074,859
1905	1,022	3,542	271,684	......	228	11,639	45,241	860	11,336,752
1906	684	2,206	349,514	......	242	18,146	38,361	614	13,678,848
1907	....	....	355,300	......	216	....	30,000	....	....
1908(*k*) .	....	....	348,300	......	180	....	33,000	....	....
1909(*k*) .	....	....	275,600	......	191	....	30,000	....	....
1910	132	2,579	309,400	......	146	27,860	49,800	577	345,160
1911	174	4,452	318,530	......	196	23,200	47,200	550	317,725
1912	53	4,017	486,072	......	213	25,056	39,500	556	354,776
1913	....	....	186,348	......	......	....	....	....	322,115
1914	....	....	....	......	......	....	....	....	297,190
1915	....	....	....	......	......	....	....	....	254,008

Year.	Sulphur.	Sulphuric Acid.	Superphosphate of Lime.	Tin.		Zinc.	
				Ore.	Metal.	Ore.	Metal.
1901..............	101,301	5,386	165,361	365	7,314	74,553	29,812
1902..............	85,839	7,793	116,093	748	8,575	69,451	36,564
1903..............	109,594	13,241	89,229	1,808	9,873	67,258	39,305
1904..............	148,547	11,212	72,921	1,344	9,352	88,083	35,737
1905..............	129,877	10,915	31,729	1,362	9,898	105,069	29,163
1906..............	131,678	5,268	44,502	1,038	7,687	106,307	26,960
1907..............	106,050	....	....	961	7,693	114,699	33,503
1908(*k*)..........	195,000	....	....	1,000	8,482	137,900	40,312
1909(*k*)..........	196,300	....	....	1,900	9,683	120,600	32,749
1910..............	202,263	14,642	132,530	1,651	8,517	193,360	19,237
1911..............	267,969	15,150	79,385	2,544	8,456	160,180	42,785
1912..............	172,181	13,169	89,059	1,726	8,503	158,429	43,795
1913..............	8,250	....	100,882	2,542	....	178,719	....
1914..............	116,018	....	231,265	....	7,216	....	30,361
1915..............	102,757	....	43,144	....	9,003	....	36,125

MINERAL AND METALLURGICAL EXPORTS OF FRANCE (*a*) (*k*)
(In metric tons)

Year.	Aluminium.	Antimony.		Arsenic.	Cement.	Coal.	Copper.		Gold. *Kg.*(*d*)
		Ore.	Metal.				Ore. (*c*)	Metal.	
1900....	324	154	336	....	232,577	1,201,210	9,197	16,791	883
1901....	307	645	741	....	242,010	908,583	16,066	14,776	1,869
1902....	748	595	666	....	210,590	910,760	20,489	14,423	1,517
1903....	666	904	1,358	....	233,835	2,238,735	12,487	11,403	3,139
1904....	664	1,191	720	....	260,686	2,384,928	14,258	12,663	1,537
1905....	928	981	815	....	275,503	(*i*)3,348,010	13,260	13,800	5,740
1906....	1,522	3,541	871	....	329,879	(*i*)1,448,000	8,056	6,130	11,727
1907....	1,118	3,460	1,270	....	366,624	(*i*)1,224,000	4,151	18,630	6,289
1908....	1,332	3,300	2,129	8,600	342,131	(*i*)1,117,000	3,600	17,845	4,455
1909....	4,425	4,000	2,408	3,267	316,486	(*i*)1,493,308	6,200	18,775	5,366
1910....	4,148	4,583	2,163	2,411	315,020	(*i*)1,580,077	4,163	20,884	7,264
1911....	4,058	3,991	1,945	832	333,043	(*i*)1,635,000	8,335	22,690	....
1912....	6,605	1,673	2,890	1,497	361,425	(*i*)2,320,349	6,374	42,307	775
1913....	....	608	....	1,850	....	....	10,154	....	....
1914....	....	....	....	....	....	913,432	....	....	....
1915....	....	....	....	....	....	239,905	....	....	....

Year.	Iron.				Lead.		Manganese Ore.
	Ore.	Pig.	Bars.	Steel.	Ore.	Metal.	
1900....................	371,799	114,361	18,763	19,535	2,345	958	8,392
1901....................	258,925	96,463	25,220	56,347	3,490	718	5,289
1902....................	422,677	213,081	23,828	121,932	2,414	648	1,948
1903....................	714,173	196,444	40,533	215,737	2,313	13,048	717
1904....................	1,219,149	191,819	40,374	246,738	1,860	13,467	1,392
1905....................	1,355,932	218,227	67,240	343,612	3,064	12,903	662
1906....................	1,759,443	143,142	58,826	236,617	1,354	997	4,103
1907....................	2,147,000	249,708	84,557	291,434	1,210	1,912	5,167
1908....................	2,384,000	171,797	86,691	360,509	6,700	1,974	1,000
1909....................	3,907,338	161,058	96,999	318,925	2,800	2,458	1,149
1910....................	4,892,542	110,086	122,543	(*k*)302,168	5,855	3,004	722
1911....................	6,160,100	104,350	171,000	100,000	9,691	2,660	902
1912....................	8,318,312	216,895	67,000	170,000	12,276	1,660	2,282
1913....................	....	....	....	....	14,263	....	1,705
1914....................	4,828,592	....	....	....	....	....	....
1915....................	94,864	....	....	....	....	....	....

Year.	Nickel, Refined.	Phosphate Rock.	Plaster.	Pyrite.	Silver. *Kg.* (*e*)	Tin (Metal).	Zinc.	
							Ore.	Spelter, Sheets and Scrap.
1901.....	1,031	81,405	101,063	52,952	16,745	438	42,995	15,022
1902.....	397	62,375	110,270	63,920	17,184	654	47,724	16,158
1903.....	720	72,252	131,245	119,173	43,690	1,994	62,731	12,657
1904.....	906	78,612	139,551	40,833	23,105	2,300	57,780	19,063
1905.....	1,583	55,240	124,561	21,257	66,904	2,611	72,512	17,802
1906.....	1,088	81,660	142,339	26,216	87,952	601	67,258	19,607
1907.....	1,414	100,508	137,356	24,417	58,199	729	54,316	21,928
1908.....	1,230	71,509	132,924	40,300	56,957	810	57,800	20,589
1909.....	1,940	47,611	120,701	40,200	56,549	886	60,000	24,729
1910.....	2,050	44,384	152,390	56,735	58,294	1,224	56,800	22,975
1911.....	880	31,413	148,952	68,919	17,256	1,520	51,737	25,500
1912.....	1,192	22,062	174,486	43,905	3,856	1,450	60,007	34,124
1913.....	....	21,128	....	....	....	....	58,203	....
1914.....	....	....	....	....	....	....	....	....
1915.....	....	....	....	....	....	....	....	....

(*a*) From *L'Economiste Francais* (representing the *Commerce Spécial*), except for 1903-06, inclusive, which are from *Tableau Général du Commerce et de la Navigation.* (*b*) Not reported. (*c*) Includes matte. (*d*) Gold and platinum in sheets, leaves, threads or jewelry, and crude platinum. (*e*) Silver in sheets, leaves, wire, and jewelry. (*f*) Includes bitumen, bituminous schist and sand, and asphaltic limestone. (*g*) Crude and refined. Transposition from hectoliters to tons was performed by assuming specific gravity of petroleum to be 0.9. (*h*) Includes chromate of soda. (*i*) Includes coke (*k*) From *Statistique de l'Industrie Minérale* in the years 1908, 1909, 1910. Steel in 1910 not classified as before. 1911, from *l'Echo des Mines et Metallurgie.*

GERMANY

The mineral production and foreign commerce of the German Empire are given in the following tables in metric tons unless otherwise specified, or in dollars, on the basis of four marks to the dollar. Figures in full-faced type are either provisional figures or estimates.

MINERAL PRODUCTION OF GERMANY (*a*)

Year.	Alum.	Aluminium Sulphate	Arsenic.		Asphaltum.	Boracite.	Cadmium. *Kg.*	Coal.	
			Ore.	Salts.				Bituminous.	Lignitic.
1900....	4,355	44,372	4,379	2,415	89,685	232	13,553	109,290,237	40,498,019
1901....	4,145	46,807	4,035	2,549	90,193	184	13,144	108,539,444	44,479,970
1902....	4,108	47,905	3,959	2,828	88,374	196	12,625	107,473,933	43,126,281
1903....	3,934	49,727	4,369	2,768	87,454	159	16,565	116,637,765	45,819,488
1904....	3,850	55,881	4,390	2,829	91,736	135	25,245	120,815,503	48,635,080
1905....	4,127	52,892	4,913	2,535	103,006	183	24,568	121,298,607	52,512,062
1906....	4,494	55,969	6,249	3,052	117,413	161	21,486	137,117,926	56,419,567
1907....	4,200	59,473	4,878	2,904	126,649	114	32,949	143,185,691	62,546,671
1908....	3,802	53,958	6,065	2,822	89,009	128	32,995	147,671,149	67,615,200
1909....	4,179	56,096	6,150	2,911	77,537	149	37,187	148,788,050	68,657,606
1910....	4,406	58,349	6,151	3,066	81,208	167	41,100	152,827,777	69,473,883
1911....	3,076	....	4,859	2,981	81,902	160	42,000	160,747,580	73,760,867
1912....	....	....	4,869	....	96,117	224	43,000	174,875,297	80,934,797
1913....	....	....	....	....	....	....	....	**191,511,000**	**87,475,000**

Year.	Cobalt, Nickel, and Bismuth Ores.	Copper.				Gold.	Graphite.
		Ore.	Matte. (*b*)	Ingots.	Sulphate.		
1899.....	1,270	733,619	95	34,634	5,142	$1,731,153	5,196
1900.....	4,495	747,749	4,207	30,929	5,076	2,030,200	9,248
1901.....	10,479	777,339	365	31,317	5,192	1,830,835	4,435
1902.....	12,433	761,921	447	30,578	4,997	1,770,361	5,023
1903.....	14,607	772,695	583	31,214	5,200	1,709,223	3,720
1904.....	14,016	798,214	641	30,264	6,584	1,819,538	3,784
1905.....	10,848	793,488	1,635	31,713	6,988	2,611,812	4,921
1906.....	....	768,523	771	32,275	6,757	2,931,750	4,055
1907.....	2,809	771,227	527	31,946	5,284	3,111,379	4,033
1908.....	8,535	727,384	328	30,001	7,117	3,162,544	4,844
1909.....	10,388	798,618	2,242	31,126	6,211	3,366,986	6,774
1910.....	10,313	925,957	3,735	34,926	5,210	3,227,250	7,415
1911.....	....	868,600	1,142	37,452	7,353	3,302,300	11,298
1912.....	12,861	969,330	2,574	49,447	5,955	**3,322,700**	12,532

Year.	Iron and Steel.				Lead.		
	Iron Ore.	Pig Iron. (*c*)	Wrought Iron and Steel.	Sulphate. (*d*)	Ore.	Pig.	Litharge.
1899....	17,989,635	8,153,133	7,532,524	10,931	144,370	129,225	3,562
1900....	18,964,294	8,520,540	7,377,275	10,913	148,257	121,513	3,088
1901....	16,570,182	7,880,087	7,033,438	11,148	153,341	123,098	4,101
1902....	17,963,591	8,529,900	8,317,231	....	167,855	140,331	4,197
1903....	21,230,650	10,017,901	9,226,898	12,243	165,991	145,319	4,428
1904....	22,047,393	10,058,273	9,239,302	13,585	164,440	137,580	4,332
1905....	23,444,073	10,875,061	10,309,690	12,949	152,725	152,590	3,786
1906....	26,734,570	12,292,819	11,307,807	13,376	140,914	150,741	4,137
1907....	27,697,127	12,875,159	12,063,632	14,033	147,272	142,271	4,325
1908....	24,278,151	11,805,321	10,930,933	15,738	156,861	164,079	5,339
1909....	25,505,409	12,917,653	11,719,239	21,838	159,852	167,920	3,059
1910....	28,709,700	14,502,183	12,988,177	18,677	148,497	159,851	3,581
1911....	29,879,361	15,280,527	14,384,271	17,002	140,154	161,287	3,687
1912....	27,199,944	15,220,881	16,508,987	....	142,839	192,618	4,135

Year.	Magnesium Salts.		Manganese Ore.	Petroleum.	Potassium Salts.				
	Chloride.	Sulphate.			Chloride.	Kainite. (f)	Sulphate.	Potassium-Magnesium Sulphate.	Other than Kainite.
1899 ...	21,370	39,540	61,329	27,027	207,506	1,108,159	26,103	9,765	1,384,972
1900 ...	19,397	48,591	59,204	50,375	271,512	1,227,873	30,853	15,368	1,822,758
1901 ...	21,018	46,714	56,691	44,095	294,666	1,498,569	37,394	15,612	2,036,325
1902 ...	19,658	39,262	49,812	49,725	267,512	1,322,623	28,278	18,147	1,962,384
1903 ...	22,990	37,844	47,994	62,680	280,248	1,557,243	36,674	23,631	2,073,720
1904 ...	25,730	39,412	52,886	89,620	297,238	1,905,893	43,959	29,285	2,179,471
1905 ...	29,017	58,568	51,463	78,869	373,177	2,387,643	47,994	34,222	2,655,845
1906 ...	38,468	43,041	52,485	81,350	403,387	2,720,594	54,490	35,211	2,821,073
1907 ...	32,891	41,105	73,105	106,379	473,138	2,624,412	60,292	33,368	3,124,955
1908 ...	29,775	42,977	67,692	141,900	511,258	2,715,487	55,756	33,149	3,383,535
1909 ...	31,526	53,812	77,177	143,244	624,994	3,181,349	68,539	38,722	3,969,554
1910 ...	32,207	57,314	80,560	145,168	741,259	4,249,667	84,583	37,438	4,062,004
1911 ...	36,764	55,179	87,297	142,992	838,420	4,425,497	107,631	42,253	5,181,379
1912 ...	85,387	99,442	185	134,986	506,744	5,889,238	123,407	54,435	....

Year.	Pyrite.	Salt.		Silver and Gold Ore.	Silver. *Kg.*	Sodium Sulphate.	Sulphur.	Sulphuric Acid.
		Rock.	Evaporated.					
1899....	144,623	861,123	571,058	13,506	467,590	79,062	1,663	813,141
1900....	169,447	926,563	587,464	12,593	415,735	90,468	1,445	829,376
1901....	157,433	985,050	578,751	11,577	403,796	76,066	963	835,000
1902....	165,225	1,010,412	572,846	11,724	430,610	90,742	....	894,409
1903....	170,867	1,095,541	598,394	11,467	396,253	83,087	219	928,190
1904....	174,782	1,079,868	621,064	10,405	389,827	75,171	209	963,384
1905....	185,368	1,165,495	612,062	10,286	399,775	68,454	205	1,228,211
1906....	196,971	1,235,041	635,171	8,066	393,442	81,175	178	1,335,128
1907....	196,351	1,285,137	665,547	8,280	386,933	80,347	176	1,402,398
1908....	219.456	1,331,984	665,651	7,653	407,185	72,667	811	1,391,653
1909....	198,688	1,370,668	647,939	7,510	400,562	71,813	1,185	1,434,709
1910....	215,708	1,424,064	669,120	6,646	420,003	84,787	1,272	1,616,336
1911....	217,459	1,436,492	645,991	4,890	439,580	82,664	1,251	1,534,455
1912....	242,121	1,352,524	671,622	595	....	....	....	1,649,681

Year.	Tin.			Uranium and Tungsten Ores.	Zinc.		
	Ore.	Block.	Chloride.		Ore.	Spelter.	Sulphate.
1900	80	2,031	(g) 143	43	639,215	155,790	6,027
1901	82	1,464	(g) 135	43	647,496	166,283	5,552
1902	104	2,779	....	31	702,504	174,927	....
1903	110	3,065	1,064	35	682,853	182,548	5,994
1904	99	4,216	816	23	715,732	193,058	6,185
1905	123	5,233	811	26	731,271	198,208	5,896
1906	....	6,597	987	....	704,590	205,691	6,092
1907	....	5,838	1,812	3	698,425	208,195	5,145
1908	111	6,374	2,266	42	706,441	216,490	5,310
1909	124	8,994	3,247	98	723,565	219,766	5,574
1910	125	11,395	3,391	95	718,316	221,395	6,308
1911	....	12,412	3,749	....	699,970	235,776	6,703
1912	(i)	10,646	3,094	70	643,598	269,161	6,413
1913	....	....	....	....	637,308	**283,190**	....

(a) From the *Vierteljahrshefte zur Statistik des Deutschen Reichs.* Where gold is reported, 1 mark = $0.238. (b) Includes black copper. (c) Includes ferro manganese and spiegeleisen. (d) Contains a small quantity of copper and iron sulphate mixed. (f) Compound of potassium chloride and magnesium sulphate. (g) Includes nickel sulphate. (i) Included with cobalt, nickel and bismuth.

MINERAL PRODUCTION OF BADEN (*a*)
(In metric tons or dollars; 4 marks = $1)

Year.	Aluminium Sulphate.	Barytes.	Coal.	Gypsum.	Manufactures of Iron.		
					Cast, Foundry.	Steel.	Wrought.
1899....	2,153	2,430	4,700	29,419	53,608	3,830	1,402
1900....	2,286	2,970	4,930	26,381	50,102	3,532	1,364
1901....	2,260	3,991	3,650	28,183	40,100	8,739	1,158
1902....	2,374	6,234	2,078	33,150	40,973	12,663	1,052
1903....	2,498	8,857	1,990	29,423	45,233	7,666	863
1904....	2,392	9,078	1,485	26,984	64,320	7,687	783
1905....	2,581	11,094	668	28,823	74,128	8,053	842
1906....	2,583	11,984	1,000	25,643	81,387	11,068	466
1907....	2,644	9,303	2,075	29,153	98,430	10,818	533
1908....	2,524	(*c*) 8,554	2,473	35,217	83,724	10,430	602
1909....	2,329	(*c*) 15,186	2,356	36,621	83,458	11,643	484
1910....	2,141	(*c*) 13,832	1,650	41,078	95,795	12,134	239
1911....	2,554	15,014	(*b*)	42,408	107,784	11,909	244
1912....	....	15,871	....	51,778	....	....	....
1913....	....	16,445	....	49,767	....	....	....

Year.	Lead Ores.	Salt.	Sulphuric Acid.	Tripoli.	Zinc Ore.
1899..................	(*b*)	31,197	13,660	12	357
1900..................	67	32,699	15,938	9	3,004
1901..................	369	32,835	17,081	8	2,870
1902..................	450	32,192	19,265	11	2,958
1903..................	350	32,383	19,755	11	3,171
1904..................	265	32,148	35,517	12	5,063
1905..................	264	31,393	40,781	12	4,046
1906..................	246	31,288	38,655	15	1,466
1907..................	278	32,078	42,831	25	2,198
1908..................	329	33,993	41,455	13	2,793
1909..................	372	34,040	42,219	14	3,253
1910..................	419	32,729	56,069	7	3,345
1911..................	191	32,118	47,796	14	3,067
1912..................	428	32,326	....	14	3,730
1913..................	480	33,502	....	13	3,882

(*a*) From the *Uebersicht der Production des Bergwerks-, Hütten-, und Salinen-Betriebes in dem Badschen Staate.* (*b*) Not reported. (*c*) Includes fluorspar.

MINERAL PRODUCTION OF BAVARIA (*a*)
(In metric tons; 4 marks = $1)

Year.	Barytes.	Kaolin.	Coal.	Coal (Lignite).	Copperas and Other Sulphate.	Emery.	Feldspar.	Fluorspar.	Graphite.
1899..	6,214	25,822	1,004,421	35,736	900	399	287	3,631	5,196
1900..	10,515	58,795	1,185,296	39,165	916	414	460	7,456	9,248
1901..	8,711	35,450	1,203,792	25,224	590	366	788	5,220	4,435
1902..	8,034	92,073	1,233,568	27,337	691	225	447	5,460	5,023
1903..	8,642	88,140	1,356,556	25,189	814	220	1,060	3,410	3,719
1904..	9,411	95,160	1,341,925	53,517	893	265	1,866	4,770	3,784
1905..	10,030	99,910	1,317,951	154,128	844	255	1,710	4,413	4,921
1906..	19,817	98,138	1,381,175	140,290	836	320	1,740	5,570	4,055
1907..	21,500	115,387	1,495,895	286,256	850	326	2,125	4,780	4,033
1908..	17,195	68,551	647,639	1,209,110	910	245	5,859	5,480	4,844
1909..	17,920	187,312	694,191	1,242,088	1,094	305	3,151	5,580	6,774
1910..	24,711	107,660	713,994	1,299,970	1,333	270	2,620	5,132	7,415
1911..	26,234	70,512	763,172	1,548,465	....	210	3,165	4,680	11,298
1912..	27,199	72,517	790,680	1,704,654	....	260	6,666	4,220	12,532
1913..	....	....	**811,000**	**1,895,000**	....	....	....	....	....

Year.	Gypsum.	Iron.						Lithographic Limestone.
		Ore.	Bar.	Cast, 1st Fusion.	Cast, 2d Fusion.	Pig.	Steel.	
1899....	29,727	181,981	61,415	(b)	92,459	83,821	134,007	11,962
1900....	35,484	178,441	49,727	29	89,692	82,327	135,411	16,030
1901....	3,581	158,820	29,978	76	76,191	72,071	109,464	9,500
1902....	31,701	157,375	38,429	56	81,874	83,123	115,354	....
1903....	30,894	162,500	36,853	41	89,804	90,168	127,141	9,890
1904....	22,766	180,342	37,780	40	108,025	92,200	125,483	13,836
1905....	46,247	182,389	36,459	24	112,875	94,242	134,755	11,360
1906....	50,763	203,596	38,508	....	122,115	97,812	150,129	....
1907....	48,975	277,280	36,883	*Nil.*	138,659	98,143	150,148	11,590
1908....	51,314	278,681	30,740	*Nil.*	128,234	131,404	176,085	9,858
1909....	51,630	279,514	33,448	*Nil.*	130,129	134,133	219,606	9,420
1910....	54,397	303,844	30,881	*Nil.*	148,261	133,679	249,198	9,790
1911....	60,390	375,409	165,683	*Nil.*	171,976	....	339,401	8,175
1912....	57,114	450,074	(c)	....	396,656	195,606	998,624	9,903

Year.	Marl. (For Cement)	Mineral Paint and Chalk.	Pyrites.	Rock Salt.	Soapstone.	Sodium Sulphate.	Sulphuric Acid.
1899....	220,716	9,287	2,516	802	2,197	1,570	123,273
1900....	180,032	11,507	2,120	1,298	1,977	1,821	123,910
1901....	76,663	84,929	2,649	1,319	2,291	1,893	115,775
1902....	178,301	13,947	2,635	832	......	....	....
1903....	200,407	19,486	2,324	879	1,866	....	....
1904....	170,698	19,107	3,427	1,139	1,709	....	....
1905....	231,310	18,285	3,301	911	1,872	....	....
1906....	230,271	22,304	3,918	1,053	......	....	....
1907....	230,583	21,219	5,085	1,393	1,999	1,439	161,868
1908....	307,820	21,310	4,037	1,285	2,199	1,743	149,079
1909....	276,974	21,692	2,952	1,860	2,329	1,265	178,371
1910....	273,727	22,357	4,466	1,192	3,083	1,416	171,131
1911....	265,899	24,258	6,316	782	3,431	2,061	170,039
1912....	341,068	30,033	6,531	1,162	3,221	....	254,708

(a) From the *Uebersicht der Production des Bergwerks-, Hütten-, und Salinen-Betriebes in dem Bayerischen Staate.* (b) Not reported. (c) With cast iron.

MINERAL PRODUCTION OF PRUSSIA (*a*)

(Metric tons; 4 marks = $1)

Year.	Alum Shale.	Antimony and Alloys.	Arsenic Products.	Arsenic Ore.	Asphalt.	Boracite.	Cadmium. *Kg.*	Coal.
1900....	103	3,025	1,585	3,531	23,891	217	13,533	101,966,158
1901....	611	2,404	1,446	3,050	26,450	164	13,144	101,203,807
1902....	219	3,542	1,514	2,909	28,035	172	12,625	100,115,315
1903....	580	3,224	1,583	3,538	23,518	135	16,565	108,809,384
1904....	106	2,774	1,573	3,527	26,348	115	25,245	112,755,621
1905....	97	2,795	1,493	4,022	28,872	151	24,568	113,000,657
1906....	634	2,953	1,551	5,430	32,270	124	21,486	128,295,948
1907....	154	3,515	1,591	4,224	39,243	90	32,949	134,044,080
1908....	80	3,596	1,646	5,015	27,444	105	32,995	139,002,378
1909....	60	3,841	1,849	5,731	19,509	123	37,187	139,906,194
1910....	46	4,969	2,068	5,789	21,595	138	41,058	143,771,612
1911....	63	5,411	1,862	4,476	19,956	147	42,575	151,324,030
1912....	104	....	....	4,870	21,241	186	....	165,302,784
1913....	180	....	....	5,008	17,795	160	....	179,861,015

Year.	Coal (Lignite).	Cobalt Ore.	Cobalt Products.	Copper.	Copper and Iron Sulphate.	Copper Ore.	Copper Matte.
1900....	34,007,542	4	52	27,156	113	747,601	4,207
1901....	37,491,412	36	66	28,422	78	765,241	281
1902....	36,228,285	76	74	27,893	119	751,496	346
1903....	38,462,766	65	87	28,386	110	761,188	488
1904....	41,153,576	41	85	27,450	95	782,049	601
1905....	44,148,751	22	99	28,874	102	769,381	1,052
1906....	47,912,721	7	98	29,166	94	755,812	525
1907....	52,660,597	*Nil.*	109	28,945	64	755,203	499
1908....	55,456,860	*Nil.*	100	27,301	50	711,921	296
1909....	56,029,554	*Nil.*	93	28,523	55	798,448	1,935
1910....	56,644,291	*Nil.*	94	30,244	44	914,519	2,060
1911....	60,531,943	*Nil.*	107	30,986	27	919,827	996
1912....	65,803,959	*Nil.*	....	....	....	967,785	....
1913....	70,051,871	*Nil.*	....	....	....	941,402	....

Year.	Copper Sulphate.	Epsom Salt.	Gold. *Kg.*	Iron.	Iron Ore.	Iron Sulphate.	Lead.
1900......	1,660	1,511	1,076.6	5,781,892	4,268,069	10,225	112,738
1901......	1,951	1,952	1,087.1	5,315,628	3,831,670	10,239	113,939
1902......	1,937	761	1,138.0	5,633,089	3,362,887	11,214	127,283
1903......	2,254	421	949.5	6,614,768	3,786,743	11,086	133,405
1904......	3,364	289	1,081.9	6,573,507	3,757,651	12,524	128,294
1905......	3,065	338	1,034.9	7,106,975	4,130,210	12,075	143,270
1906......	2,724	144	750.2	8,154,880	4,713,928	12,473	140,690
1907......	2,129	263	771.0	8,266,300	5,077,773	13,014	132,366
1908......	3,116	398	786.6	7,989,260	4,311,593	14,062	153,541
1909......	2,500	395	588.2	8,410,824	4,389,950	18,295	156,533
1910......	1,749	162	566.3	9,995,012	4,823,606	16,119	146,993
1911....	2,464	114	520.	10,477,263	4,948,711	15,468	147,538
1912......	....	....	....	....	5,331,240	....	....
1913......	....	....	....	....	5,461,670	....	....

Year.	Lead Ore.	Litharge.	Manganese Ore.	Nickel.	Nickel Ore.	Nickel Sulphate.	Ocher and Mineral Paints.
1900........	133,483	2,366	58,016	1,376	3,896	115	2,850
1901........	139,285	2,885	55,866	1,660	9,922	120	2,800
1902........	152,282	2,516	48,882	1,605	11,816	159	2,780
1903........	151,746	2,710	47,110	1,945	14,058	173	2,850
1904........	150,328	2,517	52,092	2,333	13,518	207	3,200
1905........	138,928	2,272	51,048	2,631	10,432	220	3,170
1906........	127,322	2,744	51,881	2,648	7,472	187	3,635
1907........	133,528	2,959	72,442	2,093	7,557	189	3,707
1908........	141,316	4,190	67,241	2,622	8,238	181	3,183
1909........	158,811	2,365	76,741	3,186	10,095	163	3,435
1910........	146,830	3,076	80,325	3,497	10,053	213	142
1911........	135,366	3,441	86,902	3,744	9,609	244	....
1912........	140,158	....	92,474	....	12,091	....	....
1913........	143,799	....	(*b*)	....	13,538	....	....

Year.	Petroleum.	Potassium Salts.		Pyrite.	Quick-silver. *Kg.*	Salt.	
		Kainite.	All Other.			Common.	Rock.
1900......	27,731	857,271	1,264,993	159,186	1,711	287,005	354,603
1901......	24,098	1,068,237	1,131,703	148,457	1,713	290,869	353,557
1902......	29,520	943,450	1,344,541	155,410	1,828	291,296	359,006
1903......	41,733	1,118,270	1,344,038	159,234	2,145	317,475	409,199
1904......	67,604	1,261,930	1,447,323	163,209	3,030	328,933	394,910
1905......	57,741	1,580,530	1,734,033	174,641	2,597	328,051	436,942
1906......	59,196	1,923,088	1,937,181	186,849	5,084	339,675	492,339
1907......	80,255	1,839,409	2,070,978	184,962	5,080	353,290	480,563
1908......	113,002	2,037,203	2,192,188	204,992	4,423	359,003	478,346
1909......	113,518	2,431,401	2,436,319	189,773	5,213	344,685	491,071
1910......	110,996	3,119,400	2,584,565	203,596	4,492	351,698	500,978
1911......	98,611	3,502,762	2,920,725	203,249	2,861	337,583	527,034
1912......	87,443	4,256,476	3,287,177	233,397	....	343,883	527,275
1913......	71,178	4,426,054	3,658,109	228,405	....	353,260	526,218

Year.	Silver. *Kg.*	Silver and Gold Ores.	Sulphur.	Sulphuric Acid.	Tin.	Zinc.		
						Ore.	Metal.	Sulphate.
1900......	266,577	1	1,207	593,109	2,010	636,068	155,760	3,742
1901.....	246,286	6	772	609,041	1,443	644,504	166,223	3,369
1902.....	273,901	17	250	677,798	2,753	699,392	174,892	3,381
1903.....	255,722	13	16	724,784	3,042	679,320	182,472	3,586
1904.....	252,020	8	16	868,424	4,193	710,599	192,903	3,696
1905.....	266,072	4	14	921,219	5,196	727,104	198,179	3,506
1906.....	264,427	239	16	980,188	6,570	702,933	205,632	3,630
1907.....	249,348	34	7	1,004,599	5,819	696,039	207,849	3,057
1908.....	274,154	7	706	997,931	5,330	703,394	212,991	3,223
1909.....	271,779	2	1,096	1,006,787	8,943	720,139	214,551	3,434
1910.....	277,777	0.2	1,239	1,164,015	11,345	714,855	216,362	3,875
1911.....	277,981	.....	1,239	1,219,879	12,335	696,903	230,995	4,127
1912.....	....	.....	....	....	......	647,081	....	....
1913.....	....	.....	....	....	......	649,695	....	....

(*a*) From *Zeitschrift für das Berg, Hütten, und Salinenwesen.*
(*b*) Included in "Iron Ore."

MINERAL IMPORTS OF GERMANY (*a*)

Year.	Aluminium Refined and Crude.	Ammonium Sulphate.	Antimony.	Antimony and Arsenic Ores.	Asbestos, Crude.	Asphalt.	Bituminous Rock.	Barium Chloride.	Barytes. (*b*)
1901 ...	1,090	44,408	1,494	1,098	5,500	62,299	41,733	1,768	5,764
1902 ...	1,100	42,252	1,495	1,231	3,415	88,536	36,791	2,135	5,040
1903 ...	1,155	35,168	2,281	1,741	5,727	94,377	40,873	2,374	5,534
1904 ...	2,422	35,166	2,003	1,687	5,251	85,049	38,812	2,428	6,742
1905 ...	3,252	48,005	1,680	567	7,830	3,461	64,196	2,114	7,981
1906 ...	3,886	35,366	2,044	2,417	9,828	15,095	118,238	2,559	17,246
1907 ...	3,974	33,522	2,496	4,913	11,096	4,793	128,257	2,781	12,588
1908 ...	3,204	47,265	2,670	2,073	10,034	2,587	130,063	2,256	19,969
1909 ...	8,696	58,132	2,719	2,912	11,928	1,209	98,378	1,907	14,560
1910 ...	9,892	31,400	2,982	3,347	11,729	2,932	117,763	1,955	5,782
1911 ...	10,454	24,463	3,607	6,429	12,334	133,635	17,476	2,002	7,926
1912 ...	18,112	23,098	3,400	2,891	14,790	147,784	18,409	3,674	18,666
1913 ...	15,508	34,627	3,604	3,700	14,658	145,351	....	2,598	19,466

Year.	Borax.	Bauxite.	Calcium Carbide.	Cement.	Chalk (d), Crude White.	Chrome Ore.	Coal.		Coke.
							Bitum., Arthracite, Cannel.	Lignitic.	
1901 ...	2,537	24,113	9,526	87,262	(d)29,611	18,222	6,297,389	8,108,943	400,197
1902 ...	2,057	26,698	11,287	52,018	(d)26,408	10,152	6,425,658	7,882,010	382,488
1903 ...	2,567	22,316	14,081	49,870	(d)33,362	13,919	6,766,513	7,962,123	432,819
1904 ...	2,603	27,849	14,840	60,188	(d)32,581	18,132	7,299,042	7,669,099	550,302
1905 ...	2,802	39,137	17,256	148,118	(d)35,529	11,998	9,399,693	7,945,261	713,619
1906 ...	3,044	43,177	22,819	233,119	18,871	17,124	9,253,711	8,430,441	565,561
1907 ...	2,014	59,989	25,834	241,475	16,035	19,508	13,729,849	8,963,103	584,220
1908 ...	1,903	48,064	29,024	168,504	17,606	16,974	11,661,503	8,581,966	575,091
1909 ...	2,550	45,543	26,956	224,178	15,924	22,018	12,198,634	8,166,479	673,012
1910 ...	3,181	56,287	30,712	242,663	17,700	24,470	11,195,593	7,397,719	622,452
1911 ...	5,358	37,155	36,994	253,023	23,717	16,022	10,913,948	7,069,064	598,958
1912 ...	7,978	36,348	47,984	228,896	28,031	23,201	10,380,482	7,266,116	589,713
1913 ...	7,381	38,452	46,725	168,449	32,546	23,251	10,540,018	6,986,681	592,661

Year.	Peat and Peat Coke.	Briquettes.	Cobalt and Nickel Ore.	Copper.				Copperas	Cryolite.
				Ore. and Matte.	Ingots.	Bars, Wire and Sheets.	Sulphate.		
1901 ...	15,102	92,037	12,186	4,614	58,620	786	1,211	501	1,249
1902 ...	16,696	81,854	14,630	14,630	76,050	540	2,499	807	1,332
1903 ...	14,640	84,635	36,927	13,714	83,261	568	1,691	778	1,082
1904 ...	9,071	125,477	14,555	7,949	110,231	719	1,735	765	1,139
1905 ...	11,439	191,753	39,590	10,137	102,218	927	2,180	666	1,143
1906 ...	19,428	162,650	22,557	9,941	126,071	409	1,702	621	(k)
1907 ...	15,238	195,403	29,296	19,295	124,116	772	4,519	1,165	(k)
1908 ...	15,266	192,391	17,402	17,456	157,669	952	5,078	7,234	(k)
1909 ...	13,208	211,058	10,186	26,488	154,673	416	6,550	5,954	(k)
1910 ...	16,188	241,267	9,937	22,194	181,551	403	3,952	4,336	(k)
1911 ...	14,517	210,933	14,897	23,327	191,590	520	4,145	3,323	(k)
1912 ...	11,040	187,736	14,987	23,192	200,608	332	7,074	5,925	(k)
1913 ...	11,796	147,416	13,658	27,594	225,392	......	3,869	2,954	(k)

Year.	Gold, Silver and Platinum Ores.	Graphite	Gypsum.	Iodine.	Iron.		Lead.		
					Ore.	Pig.	Ore.	Pig and Scrap.	Lead White.
1901 ...	8,764	17,374	7,622	266	4,370,022	267,503	100,196	52,886	423
1902 ...	6,585	19,392	8,177	220	3,957,403	143,040	71,078	39,006	357
1903 ...	4,386	20,953	8,328	320	5,225,336	158,347	67,573	52,440	442
1904 ...	5,960	23,533	9,550	272	6,061,127	178,256	83,807	61,388	622
1905 ...	6,225	26,143	11,247	377	6,085,196	158,700	92,667	78,528	2,488
1906 ...	4,819	28,175	11,062	297	7,629,730	409,083	90,027	71,191	2,342
1907 ...	3,601	29,405	14,662	147	8,476,076	443,624	137,861	75,200	3,037
1908 ...	1,922	34,491	14,599	194	7,732,949	252,779	133,597	77,218	3,558
1909 ...	1,759	29,191	11,285	369	8,366,599	134,230	111,017	76,930	2,890
1910 ...	2,552	30,733	10,873	363	9,816,822	136,330	112,151	81,541	2,780
1911 ...	2,947	32,812	11,973	303	10,812,595	129,850	143,598	100,515	3,938
1912 ...	2,200	37,633	10,628	260	12,120,090	135,722	122,847	93,585	2,709
1913 ...	1,932	37,168	8,818	258	14,019,045	124,236	142,977	83,781	1,980

Year.	Magnesite.	Manganese Ore.	Mineral Pigments.	Nickel.	Ozokerite.	Petroleum Products		Phosphorus.
						Illuminating Oil.	Lubricating Oil.	
1901....	8,897	204,420	9,403	1,947	1,981	985,904	118,999	313
1902....	12,237	222,010	7,719	1,458	1,585	1,006,829	125,667	350
1903....	14,958	204,647	9,888	1,507	1,663	1,067,697	147,837	222
1904....	15,877	223,709	10,494	1,712	1,300	1,076,324	142,929	220
1905....	19,459	255,760	11,473	1,955	1,114	1,070,252	143,926	198
1906....	25,527	262,311	3,960	3,478	1,303	984,134	180,989	208
1907....	30,857	331,171	2,166	2,182	1,653	1,115,205	226,609	165
1908....	28,305	393,327	1,635	3,058	1,447	1,123,632	216,887	141
1909....	29,994	334,133	13,804	3,745	1,447	1,085,839	216,987	179
1910....	40,218	384,445	15,100	4,606	1,729	1,135,886	230,516	169
1911....	47,930	487,872	15.703	2,598	1,591	955,482	260,242	200
1912....	69,064	420.709	17,874	2,027	1,479	795,011	241,030	205
1913....	64,974	680,371	18,971	3,315	1,363	745,466	248,035	209

Year.	Phosphate Rock.	Potassium Salts.							Pumice Stone. (*g*)	Pyrite.
		Chloride.	Cyanide. (*f*)	Iodide.	Nitrate.	Carbonate.	Hydroxide.	Sulphate.		
1901....	351,155	462	2	1,529	1,758	1,529	165	680	2,336	488,633
1902....	430,043	261	3	10	1,889	2,112	42	266	2,070	482,095
1903....	461,092	40	3	8	2,163	1,850	52	81	2,697	519,317
1904....	508,634	47	2	10	2,349	1,955	61	121	3,000	503,503
1905....	501,048	223	3	30	2,156	1,693	24	131	3,240	552,184
1906....	531,195	181	3	18	1,918	2,099	44	257	5,463	579,355
1907....	579,505	1,615	1	8	1,815	2,304	92	141	5,443	742,526
1908....	736,127	49	4	7	2,200	1,773	50	169	6,154	659,871
1909....	663,400	55	2	4	2,853	1,750	64	101	6,639	691,213
1910....	723,271	72	2	8	1,979	2,366	63	66	7,446	792,735
1911....	831,027	1,160	33	13	2,114	2,616	67	61	9,659	862,214
1912....	902,844	46	5	11	597	2,321	62	44	8,365	1,073,285
1913....	928,798	15	3	13	402	2,760	42	44	8,801	1,023,952

Year.	Quicksilver.	Salt.	Slag and Slag Wool.	Sodium Salts.			Strontianite. (*n*)
				Soda, Calcined.	Nitrate (Chile Saltpeter).	Sulphate and Sulphite.	
1901.....	651	23,901	733,931	178	529,568	7,921	19,739
1902.....	648	26,404	831,282	121	467,024	7,308	34,035
1903.....	674	20,118	877,394	114	467,130	6,058	24,183
1904.....	691	18,743	846,738	179	506,172	9,598	18,055
1905.....	729	20,726	888,665	143	540,916	4,752	13,720
1906.....	698	16,997	813,388	189	593,218	7,405	5,212
1907.....	831	23,109	568,046	257	591,131	10,446	5,595
1908.....	648	24,975	562,853	293	604,457	4,404	4,211
1909.....	723	19,319	492,771	181	665,450	9,214	4,277
1910.....	836	30,443	766,320	105	749,945	9,302	4.852
1911.....	919	29,067	685,943	559	730,939	5,976	3,251
1912.....	990	17,887	1,248,693	1,987	812,898	5,609	4,259
1913.....	961	21,422	....	2,633	774,298	10,074	3,965

Year.	Sulphur.	Sulphuric Acid.	Super-phosphate.	Tin, Crude.	Zinc.			
					Ore.	Spelter.	Drawn or Rolled.	Zinc White, Zinc Gray, Lithophone.
1901....	32,750	18,502	107,365	12,910	75,533	21,250	306	3,673
1902....	32,798	22,205	109,374	13,760	61,407	25,946	134	3,986
1903....	41,545	13,418	82,740	13,925	67,156	25,749	237	4,667
1904....	41,030	16,087	91,288	14,352	93,515	26,389	151	6,461
1905....	39,989	33,837	109,666	13,501	126,577	29,583	54	7,802
1906....	41,390	74,536	76,384	14,098	178,953	39,314	97	9,140
1907....	44,700	59,753	62,877	12,814	184,703	28,459	134	10,189
1908....	44,066	61,391	71,879	14,039	199,840	32,622	286	7,080
1909....	42,941	74,384	80,512	13,537	201,110	44,514	99	7,002
1910....	46,796	86,743	78,873	14,297	240,584	39,328	246	9,239
1911....	46,054	99,653	71,119	14,500	262,399	48,355	467	7,697
1912....	42,284	98,573	62,400	15,550	293,090	56,937	1,003	9,367
1913....	46,737	130,257	53,193	14,261	313,269	57,641	725	9,108

MINERAL EXPORTS OF GERMANY (*a*)

Year.	Aluminium Refined and Crude.	Aluminium Wares, etc.	Aluminium Sulphate.	Ammonium.		Antimony and Arsenic Ores.	Antimony.	
				Carbonate and Chloride.	Sulphate.		Metallic.	Salts.
1901....	282	2,270	31,171	3,196	9,842	283	76	826
1902....	410	2,608	34,005	3,351	5,744	410	105	954
1903....	353	2,865	28,513	2,778	5,592	427	83	873
1904....	407	3,077	29,311	3,106	10,696	486	250	964
1905....	1,192	3,476	34,776	3,579	27,589	287	218	1,097
1906....	1,111	1,321	25,937	3,555	37,288	548	221	997
1907....	1,119	1,142	24,759	3,118	57,439	930	255	1,168
1908....	590	642	22,376	1,161	73,186	588	146	1,030
1909....	492	1,273	58,723	1,093	58,722	577	160	1,090
1910....	616	1,755	93,069	1,500	93,069	571	198	1,047
1911....	768	1,331	30,107	4,895	74,410	612	298	1,208
1912....	2,074	4,184	32,469	5,292	57,268	569	132	1,155
1913....	2,703	5,667	31,772	5,401	75,868	502	702	1,461

Year.	Arsenic.		Asbestos.	Barytes. (*b*)	Barium.		Bauxite.	Borax.	Bromine.
	Metallic.	White, etc.	Crude.		Chloride and Salts of.	White.			
1901 ...	28	1,534	638	67,526	6,803	2,765	137	2,563	228
1902 ...	46	2,036	709	56,026	7,358	2,922	32	2,836	153
1903 ...	32	1,903	513	72,455	8,417	3,187	19	2,779	155
1904 ...	50	1,956	738	69,564	8,596	3,777	21	2,741	208
1905 ...	40	1,753	1,173	81,134	9,550	4,382	6	2,720	156
1906 ...	....	2,282	1,938	90,819	6,541	10,721	398	2,795	172
1907 ...	(*m*)45	1,733	1,707	111,209	4,189	8,454	517	3,049	118
1908 ...	(*m*)65	1,956	1,345	91,111	3,389	5,190	783	2,379	227
1909 ...	(*m*)54	1,012	1,740	90,555	5,340	4,888	1,116	2,735	206
1910 ...	(*m*)57	1,507	1,537	114,264	6,403	5,528	863	2,916	225
1911 ...	71	1,973	1,503	128,452	6,180	6,834	960	3,199	229
1912 ...	73	2,400	1,891	142,957	7,389	8,298	400	3,330	187
1913 ...	....	2,612	1,461	158,065	5,649	7,647	355	3,433	239

Year.	Coke.	Peat and Peat Coke.	Briquets.	Cobalt and Nickel Ore.	Copper.			
					Ore and Matte.	Bars, Sheets and Wire.	Ingots.	Sulphate.
1901....	2,096,931	11,588	529,765	96	26,678	7,700	5,097	1,942
1902 ..	2,182,383	13,410	697,799	3	17,031	10,599	4,678	1,366
1903....	2,523,351	16,986	895,145	1	15,986	10,715	4,333	1,880
1904....	2,716,855	14,830	917,526	83	19,235	12,594	4,223	2,231
1905....	2,761,080	16,009	936,694	107	28,908	10,006	5,958	2,180
1906....	3,415,347	15,680	1,095,029	(i)	6,414	10,728	7,241	3,018
1907....	3,792,580	25,746	1,260,135	(i)	20,950	13,411	6,113	2,016
1908....	3,577,496	26,817	1,493,054	(i)	21,729	17,209	6,868	2,994
1909....	3,444,791	23,579	1,620,460	(i)	22,437	15,395	6,495	1,290
1910....	4,125,898	20,360	1,988,177	(i)	23,751	19,351	7,654	2,108
1911....	4,555,477	35,855	2,477,492	(i)	27,396	19,669	7,106	3,346
1912....	5,850,350	60,557	2,746,536	(i)	21,514	20,245	7,854	3,812
1913....	6,411,418	86,920	3,163,742	(i)	25,221	....	7,208	4,013

Year.	Bromine Salts.	Calcium.		Cement.	Chalk, Crude White.	Chromium.		Coal.	
		Car-bide.	Ch-lo ride.			Ore.	Alum.	Bituminous, Anthracite and Cannel.	Lignitic
1901 ...	249	275	888	560,612	(d) 14,134	581	1,299	15,269,267	21,718
1902 ...	357	126	1,346	699,378	(d) 8,475	846	1,758	16,101,141	21,766
1903 ...	435	335	1,831	742,381	(d) 12,211	37	1,921	17,389,934	22,499
1904 ...	411	608	2,381	635,248	(d) 11,359	47	2,432	17,996,726	22,135
1905 ...	634	709	2,831	675,664	(d) 13,081	43	2,507	18,156,998	20,118
1906 ...	643	545	(l)	736,579	4,287	(h) 36	2,942	19,550,964	18,759
1907 ...	655	918	(l)	692,982	2,919	(h) 149	3,110	20,056,503	22,065
1908 ...	506	844	(l)	528,847	2,108	(h) 110	3,215	21,190,777	27,877
1909 ...	486	968	(l)	611,893	4,395	(h) 5,023	3,023	23,350,705	39,815
1910 ...	323	1,482	(l)	725,356	3,359	(h) 386	3,998	24,257,651	62,441
1911 ...	....	2,120	(l)	845,850	1,537	(h) 1,795	2,815	27,412,218	58,071
1912 ...	372	971	(l)	1,056,622	2,890	(h) 778	3,221	31,145,057	56,966
1913 ...	405	....	(l)	1,129,563	3,409	(h) 681	3,313	34,573,514	60,345

Year.	Copperas.	Cryolite.	Fluor-spar.	Graph-ite.	Gypsum.	Iodine.	Iron.	
							Ore.	Pig.
1901.......	4,125	367	13,436	1,667	40,397	27	2,389,870	150,448
1902.......	4,360	486	14,177	1,691	42,859	24	2,868,068	374,256
1903.......	3,986	349	13,028	1,810	51,874	29	3,343,510	418,072
1904.......	3,514	310	13,540	1,815	55,043	30	3,440,846	225,897
1905.......	4,495	286	15,019	1,971	52,886	27	3,698,563	380,824
1906.......	4,712	(k)	15,493	2,013	63,516	46	3,851,791	479,772
1907.......	6,212	(k)	16,624	2,176	70,737	44	3,904,400	275,170
1908.......	4,393	(k)	14,925	2,469	60,992	51	3,067,737	257,849
1909.......	2,232	(k)	14,534	2,377	63,220	59	2,825,007	471,045
1910.......	2,929	(k)	17,988	3,424	89,590	70	2,952,634	786,854
1911.......	4,151	(k)	23,073	3,822	102,754	73	2,581,698	829,393
1912.......	3,386	(k)	21,145	4,501	108,624	79	2,309,628	1,016,261
1913.......	5,382	(k)	25,523	5,423	132,693	92	2,613,158	782,911

Year.	Lead.					Lime, Chloride of.	Mag-nesite.	Magne-sium Chloride.	Manga-nese Ore.
	Ore.	Pig and Scrap.	Litharge.	White.	Red.				
1901 ...	891	20,820	4,876	16,966	7,776	32,705	2,485	16,102	5,584
1902 ...	2,024	23,100	4,072	19,070	8,372	29,694	2,955	14,757	4,528
1903 ...	1,270	30,243	5,175	20,765	7,617	28,849	2,812	17,008	11,138
1904 ...	1,312	23,169	5,410	16,638	7,544	30,078	1,917	16,706	5,536
1905 ...	1,496	32,515	4,466	16,478	8,902	30,667	2,552	21,673	4,116
1906 ...	1,915	27,067	2,493	14,022	9,450	29,485	2,843	26,708	2,555
1907 ...	1,296	38,259	4,470	13,651	9,371	24,946	3,264	29,566	3,554
1908 ...	1,189	29,967	5,242	13,733	9,602	23,895	4,021	27,525	2,333
1909 ...	2,556	31,674	4,750	10,583	9,058	27,314	3,702	31,334	4,488
1910 ...	2,382	31,025	4,865	13,595	10,444	24,716	5,399	35,352	4,557
1911 ...	3,746	32,063	5,436	14,962	11,321	27,107	4,496	43,896	9,615
1912 ...	3,273	38,122	6,480	12,750	10,116	32,254	7,132	39,559	7,790
1913 ...	4,458	41,369	6,203	12,402	8,898	36,473	5,857	55,505	9,388

Year.	Mineral Pigments.	Nickel.	Ozokerite.	Petroleum Products. (*f*)		Phosphor-us.	Phosphate Rock.
				Illuminating Oil.	Lubricating Oil.		
1901........	12,671	390	1,700	655	963	149	2,260
1902........	14,392	689	1,856	824	1,177	260	1,103
1903........	15,161	700	2.027	701	1,975	286	4,342
1904........	16,395	1,203	2,447	760	1,763	236	3,222
1905........	17,603	1,034	2,757	7,286	1,746	228	3,720
1906........	4,290	954	509	673	9,982	228	5,484
1907........	4,097	930	692	770	10,552	165	1,494
1908........	15,675	1,349	921	1,008	10,852	160	1,196
1909........	18,130	1,606	1,300	588	11,621	168	5,429
1910........	19,355	1,381	1,642	472	17,141	160	5,044
1911........	22,426	1,592	1,295	274	18,905	192	10,591
1912........	27,313	1,677	1,167	244	19,635	219	7,032
1913.......	30,348	1,673	1,999	....	....	192	6,885

Year.	Potassium Salts.						Potassium and Potas-sium-mag-nesium Sulphate.	Pum-ice Stone. (*g*)	Pyrite.
	Carbonate	Cyanide. (*f*)	Chloride.	Hydroxide.	Iodide.	Nitrate.			
1901 ...	15,567	2,089	118,959	14,892	145	13,439	37,216	699	23,680
1902 ...	14,041	3,257	106,925	13,804	152	9,734	40,487	691	35,370
1903 ...	13,121	2,017	125,302	13,006	154	9,671	56,455	794	32,611
1904 ...	10,777	3,290	140,765	24,963	174	10,405	64,400	943	30,666
1905 ...	11,963	4,005	156,440	22,246	170	12,140	67,286	939	35,195
1906 ...	12,543	5,049	171,994	21,772	168	11,564	54,557	1,578	35,829
1907 ...	13,314	5,210	173,638	20,254	146	12,668	128,344	2,590	24,183
1908 ...	13,009	4,887	174,345	25,048	127	10,643	181,975	6,055	16,384
1909 ...	13,797	6,283	216,286	27,095	122	12,498	201,393	9,140	11,564
1910 ...	13,099	6,329	266,783	29,094	124	14,728	273,614	7,643	9,871
1911 ...	14,584	6,554	329,751	28,921	133	16,430	392,129	22,075	11,015
1912 ...	12,991	6,718	286,614	26,623	143	14,451	134,079	19,978	27,917
1913 ...	16,271	6,678	393,320	44,113	160	16,058	192,565	4,052	28.214

Year.	Quick-silver.	Salt.	Slag and Slag Wool.	Sodium Salts.					
				Bicar-bonate.	Carbon-ate.	Hydrox-ide.	Nitrate. (Chile Saltpeter).	Soda, Calcined.	Sulphate and Sulphite.
1901...	27	286,424	27,269	1,086	1,382	4,926	13,481	45,967	45,462
1902...	109	328,324	22,726	954	2,449	5,650	14,737	33,109	56,748
1903...	62	399,184	14,674	1,016	2,982	5,886	17,583	46,086	47,660
1904...	43	347,351	38,587	1,524	3,050	5,084	21,075	43,590	45,506
1905...	48	284,203	28,032	1,881	4,113	5,925	20,531	46,768	54,377
1906...	21	97,878	49,912	2,120	5,860	6,101	22,099	41,598	64,217
1907...	26	92,288	46,680	1,764	2,680	7,462	22,715	36,802	69,231
1908...	26	318,395	74,821	1,713	3,842	7,626	23,549	56,839	78,510
1909...	29	364,107	61,674	1,292	2,968	8,314	28,019	54,493	74,512
1910...	31	370,074	58,832	1,370	5,994	9,295	27,095	56,545	89,208
1911...	36	374,633	88,423	1,598	1,782	10,635	27,937	60,102	89,110
1912...	37	430,137	128,740	1,584	1,057	12,460	27,431	66,760	85,416
1913...	53	432,387	....	1,869	1,354	13,030	27,507	69,993	83,239

Year.	Sodium and Potassium Salts.		Stassfurt Salts.	Strontium.		Sulphur.	Sulphuric Acid.
	Chromates.	Sulphides.		Carbonate. (n)	Salts.		
1901	2,791	2,763	592,347	384	1,022	621	42,853
1902	2,656	4,565	499,220	762	1,546	576	47,666
1903	2,977	5,845	501,385	819	1,389	1,052	50,109
1904	2,272	5,489	631,762	613	1,207	1,418	52,696
1905	2,133	6,569	852,454	613	1,386	1,198	48,701
1906	2,877	6,730	831,293	1,726	1,578	1,582	52,720
1907	3,016	8,103	839,889	1,462	1,671	1,501	49,950
1908	4,402	6,536	818,677	1,494	1,822	1,765	60,588
1909	4,789	7,596	946,457	2,636	1,832	1,935	63,817
1910	4,246	8,679	1,181,208	2,456	1,275	2,727	66,581
1911	5,193	7,837	1,154,974	595	....	1,757	64,888
1912	5,167	7,640	....	1,830	138	1,746	75,962
1913......	5,667	9,226	....	1,958	330	3,472	64,968

Year.	Super-phosphate.	Tin, Crude.	Zinc.				Zinc White, Zinc Gray and Litho-phone.
			Ore.	Spelter and Scrap.	Drawn or Rolled.	Sulphate.	
1900.......	77,118	1,626	34,941	51,899	16,709	382	20,729
1901.......	79,190	1,683	14,002	54,490	16,517	324	24,201
1902.......	77,818	2,271	46,965	70,292	17,015	430	28,400
1903.......	99,672	2,581	40,458	67,057	15,715	264	27,527
1904.......	129,925	2,965	40,488	70,063	17,917	332	26,898
1905.......	115,886	3,259	38,972	67,675	18,982	296	27,877
1906.......	104,713	4,845	42,546	69,142	17,794	426	26,296
1907.......	115,049	4,244	34,863	93,649	21,484	425	30,453
1908.......	125,464	3,707	39,450	75,290	18,661	347	26,372
1909.......	168,988	5,431	51,994	82,225	18,961	342	25,970
1910.......	211,812	7,530	59,440	8,803	26,623	334	36,350
1911.......	221,521	7,582	48,998	81,042	36,093	387	34,419
1912.......	271,349	6,368	51,242	105,328	26,379	....	44,169
1913.......	282,653	6,437	44,731	109,606	24,965	....	46,106

(a) From *Statistisches Jahrbuch für das Deutsches Reich.* (b) Includes celestite. (d) Includes precipitated chalk. (f) Includes sodium cyanide. (g) Includes tripoli. (h) Includes nickel ore. (i) Included under chromium ore. (k) Included under bauxite. (l) Included under magnesium chloride. (m) Includes all alkali metals. (n) Includes witherite.

GREECE

The statistics of mineral production in Greece, according to the latest available reports, are summarized in the following table:

MINERAL PRODUCTION OF GREECE (*a*)
(In metric tons or dollars; 1 drachma = 20 cents)

Year.	Chrome Ore.	Emery.	Gypsum.	Iron Ore.	Iron Ore, Manganiferous.	Lead, Soft.	Lead Ore, Argentiferous.	Lead, Argentiferous.	Lead, Fume.	Lignite.
1902 ..	11,680	4,727	172	364,340	170,040	(*b*)	430	14,048	1,647	6,500
1903 ..	8,478	5,586	94	531,804	152,740	(*b*)	(*b*)	12,361	(*b*)	8,687
1904 ..	6,530	6,182	117	422,159	108,319	(*b*)	(*b*)	15,186	(*b*)	13,500
1905 ..	8,900	6,972	57	465,622	89,687	(*b*)	(*b*)	13,729	(*b*)	11,757
1906 ..	11,530	7,718	85	680,620	96,382	(*b*)	(*b*)	12,308	(*b*)	11,582
1907 ..	11,730	10,652	105	768,863	92,970	(*b*)	(*b*)	13,814	(*b*)	11,719
1908 ..	4,350	7,471	61	531,368	65,757	(*b*)	(*b*)	15,892	(*b*)	8,786
1909 ..	9,600	8,193	208	475,616	54,926	(*b*)	(*c*)	14,948	(*b*)	3,873
1910 ..	9,450	12,939	243	535,482	50,015	(*c*)	8,355	16,710	(*b*)	1,500
1911 ..	12,915	10,544	1,263	496,731	27,482	......	182,324	14,283	....	....
1912 ..	6,468	3,359	127	376,931	12,212	......	175,463	14,489	....	....
1913 ..	6,342	5,560	2,230	310,078	6,323	......	159,348	18,309	....	170
1914 ..	7,059	16,112	639	299,286	1,315	......	151,581	20,684	....	20,002
1915 .	10,420	14,338	1,648	157,430	1,041	......	104,905	11,595	....	39,745

Year.	Magnesite.			Manganese Ore.	Puzzolan.	Sea Salt.	Sulphur.	Zinc Ore.	
	Crude.	Bricks.	Calcined.					Blende.	Calamine, Calcined.
1902...	23,020	935	4,730	14,960	32,514	25,200	1,391	(*b*)	18,670
1903...	28,415	(*b*)	(*b*)	9,340	40,978	26,000	1,266	(*b*)	12,350
1904...	9,133	(*b*)	(*b*)	8,549	44,644	27,000	1,225	(*b*)	19,913
1905...	37,063	(*b*)	(*b*)	8,171	41,900	25,201	1,126	(*b*)	22,562
1906...	40,584	(*b*)	(*b*)	10,040	30,622	25,167	(*b*)	(*b*)	26,258
1907...	55,816	(*b*)	(*b*)	11,139	39,637	26,966	(*b*)	(*b*)	30,346
1908...	63,079	(*b*)	(*b*)	10,750	52,312	23,988	(*b*)	28,739	24,101
1909...	56,797	294	16,609	5,374	46,238	29,448	(*b*)	41,656	30,159
1910...	18,073	295	19,982	41	31,609	25,978	(*b*)	(*f*)5,845	28,898
1911...	86,956	275	27,530	(*e*) 733	31,647	26,952	(*h*)31,905	35,856	30,512
1912...	106,338	496	33,848	(*e*)8,082	19,400	31,400	(*h*)31,938	39,585	28,912
1913...	98,517	....	31,815	(*e*) 556	24,906	19,215	(*h*)128,932	30,717	20,646
1914...	136,701	493	28,563	558	28,909	29,717	(*h*)129,129	32,440	22,308
1915...	159,981	161	27,248	408	13,471	16,856	(*h*) 12,121	33,121	20,209

(*a*) Statistics up to 1903 communicated by E. Grohmann, Seriphos. Statistics for 1903 and subsequent years from *Statistique du Mouvement Minier de Grèce*. The figures represent sales or shipments. (*b*) Not reported. (*c*) No sales, but production of lead ore is reported at 240,013 tons in 1909 and 185,207 tons in 1910. (*e*) Sales. (*f*) Production in 1910 was 37,108 tons. (*h*) Including pyrite.

INDIA

The official statistics of mineral production in British India are summarized in the subjoined table:

MINERAL PRODUCTION OF INDIA (*a*)

(In metric tons or dollars; £1 = $5)

Year.	Amber.	Coal.	Chromite.	Diamonds *Carats.*	Gold. (*c*)	Graphite.	Iron Ore.	Jade. (*e*) *Cwt.*	Magnesite.
1902...	$2,160	7,543,625	.....	....	$9,611,985	4,648	(*d*)77,273	174	3,597
1903...	2,070	7,557,754	289	....	11,203,926	3,448	(*d*)62,337	99	838
1904...	4,190	8,348,561	3,654	286.5	11,513,340	2,955	72,832	130	1,193
1905...	4,725	8,552,422	2,751	172.4	11,760,957	2,361	104,984	106	2,645
1906...	3,545	9,940,247	4,445	305.9	10,852,546	2,642	92,933	116	1,861
1907...	1,925	11,325,696	18,596	628.0	10,348,795	2,472	69,829	2,636	189
1908...	1,820	12,974,558	4,821	140.8	10,597,404	2,919	73,457	3,211	7,655
1909...	1,435	12,060,550	9,398	147.3	10,728,900	3,182	84,774	2,487	749
1910...	1,415	12,249,744	1,765	77.7	10,717,300	4,319	55,461	1,908	5,265
1911...	665	12,919,587	3,865	53.0	10,890,804	4,047	372,049	2,063	3,546
1912....	895	14,942,340	2,936	27.8	11,054,608	*Nil*	589,508	806	15,626
1913...	145	16,467,337	5,767	115.7	11,152,408	*Nil*	376,779	3,281	16,457
1914...	1,370	16,729,338	5,982	54.7	11,378,435	*Nil*	448,741	3,765	1,707
1915...	995	17,379,305	3,828	36.0	11,531,671	71	396,554	3,693	7,570

Year.	Manganese Ore.	Mica.	Petroleum. *Gallons.*	Rubies. *Carats.*	Salt.	Saltpeter (Potassium Nitrate.)	Tin and Tin Ore.
1902.....	160,311	1,139	56,607,688	169,965	1,056,899	17,320	101
1903.....	174,563	870	87,859,069	227,213	836,394	18,711	112
1904.....	152,601	1,126	118,491,382	265,901	1,122,731	14,200	71
1905.....	250,788	1,302	144,798,444	266,584	1,212,504	15,745	77
1906.....	579,231	2,669	140,553,122	329,692	1,176,269	16,822	97
1907.....	916,770	2,652	152,045,677	604,217	1,120,427	18,664	80
1908.....	685,135	2,720	176,646,320	356,044	1,300,416	19,620	96
1909.....	654,974	1,671	233,678,087	265,010	1,274,682	20,953	85
1910.....	813,721	1,153	214,928,647	262,019	1,577,823	16,140	167
1911.....	681,015	1,722	225,792,094	288,213	1,347,116	14,679	189
1912.....	643,209	2,227	249,083,518	323,245	1,477,971	14,797	382
1913.....	828,088	2,324	277,555,225	278,706	1,496,760	14,461	359
1914.....	693,824	2,057	259,342,710	304,872	1,529,002	15,738	374
1915.....	457,668	1,379	287,093,576	251,449	1,956,311	18,389	568

(*a*) Records of the Geological Survey of India. (*b*) Not reported. (*c*) £1 = $4.866. (*d*) Production of iron ore in Bengal only. (*e*) Exports in cwt. of 112 lb.

ITALY

The following tables itemize the statistics of the production and the foreign commerce of mineral and metallurgical products in Italy:

MINERAL PRODUCTION AND REFINED PRODUCTS OF ITALY (*a*)
(In metric tons or dollars; 5 lire = $1)

Year.	Alum.	Aluminium Sulphate.	Alunite.	Antimony.	Antimony Ore.	Asphalt, Mastic, and Bitumen.	Asphaltic Rock.	Barytes.
1901	1,075	2,260	4,900	1,721	8,818	31,814	104,111	13,245
1902.....	3,995	2,620	8,200	1,574	6,116	33,684	64,245	13,245
1903.....	3,980	2,210	8,100	905	6,927	35,757	89,078	12,420
1904.....	2,490	2,210	8,000	836	5,712	30,817	111,390	12,290
1905.....	2,975	2,740	8,500	327	5,083	26,838	106,586	12,670
1906.....	2,878	2,800	7,500	537	5,704	34,386	130,225	12,020
1907.....	3,175	3,010	7,600	610	7,892	38,568	161,126	15,732
1908.....	2,875	2,100	6,165	345	2,821	34,761	134,163	15,432
1909.....	2,580	2,750	5,636	59	1,077	39,165	111,067	16,240
1910.....	2,510	2,773	6,081	*Nil*	2,194	41,705	162,212	14,420
1911.....	2,725	2,493	6,100	*Nil*	2,441	50,179	188,133	13,620
1912.....	1,299	2,727	6,002	*Nil*	1,878	52,707	181,397	13,420
1913.....	1,009	3,308	5,976	76	1,822	56,750	171,097	12,970
1914.....	1,307	3,229	3,700	138	555	33,752	119,853	12,970
1915.....	1,329	2,094	4,850	548	4,334	25,701	47,650	17,850

Year.	Borax, Refined.	Boric Acid.		Coal. (*c*)	Coal (Briquettes).	Coke.	Copper.		
		Crude.	Refined.				Ore.	Ingot, etc.	Sulphate.
1901...	544	2,558	347	425,614	754,800	490,803	107,750	2,639	15,374
1902...	375	2,763	238	414,569	713,430	528,765	101,142	10,230	14,601
1903...	377	2,583	187	346,887	724,993	554,559	114,823	11,217	18,164
1904...	569	2,624	314	362,151	903,610	607,297	157,503	11,873	17,237
1905...	1,007	2,700	749	412,916	842,250	627,984	149,035	16,132	26,212
1906...	1,062	2,561	562	473,293	829,277	672,689	147,137	15,456	34,270
1907...	880	2,305	466	453,137	787,087	717,704	167,619	17,491	45,263
1908...	1,024	2,520	429	480,029	822,699	813,842	106,629	18,280	42,598
1909...	1,110	2,431	578	555,073	924,479	999,381	90,272	20,005	28,551
1910...	912	2,502	695	562,154	918,055	1,160,543	68,369	22,467	36,236
1911...	738	2,648	444	555,137	794,206	363,493	68,136	22,908	44,626
1912...	813	2,309	760	663,812	876.565	437,706	86,001	26,659	52,311
1913...	1,070	2,410	743	701,081	896,091	1,336,382	89,487	24,625	44,497
1914...	1,164	2,537	838	781,338	968,600	1,276,318	88,953	1,839	31,302
1915...	829	2,497	1,277	953,082	721,409	1,365,109	74,470	940	41,272

Year.	Gold.		Graphite.	Iron and Steel.				
	Ore.	Bullion.		Ore.	Pig.	Bar, Sheet, Pipe, Wire, etc.	Tin Plate.	Steel.
1901.....	890	$8,120	10,313	232,299	15,819	180,729	7,550	123,310
1902.....	1,215	10,269	9,210	240,705	30,640	163,055	8,800	108,864
1903.....	5,734	24,667	7,920	374,790	90,744	177,392	11,275	154,134
1904.....	6,746	36,996	9,765	409,460	112,598	181,385	16,655	177,086
1905.....	1,200	7,200	10,572	366,616	181,248	205,915	18,560	244,793
1906.....	6,543	42,720	10,805	384,217	180,940	236,946	16,350	332,924
1907.....	13,475	41,000	10,989	517,952	148,996	248,157	24,423	346,749
1908.....	14,671	48,223	12,914	539,120	158,100	302,509	28,277	437,674
1909.....	2,890	18,230	11,583	505,095	254,904	281,098	35,880	608,795
1910.....	2,147	11,746	12,510	551,259	399,700	311,210	42,670	670,983
1911.....	2,080	16,440	12,621	373,786	302,931	303,223	25,662	697,958
1912.....	2,366	13,271	13,170	582,066	379,989	179,516	28,916	801,907
1913.....	2,047	23,580	11,145	603,116	426,755	591,763	29,185	846,085
1914....	205	(*b*)	8,567	706,246	385,340	705,273	26,284	796,152
1915.....	296	1,420	6,176	679,970	377,510	(*b*)	29,094	1,009,240

Year.	Lead. Ore.	Lead. Pig.	Manganese Ore.	Manganiferous Iron Ore.	Marble.	Petroleum. Crude.	Refined Petroleum, Benzene, etc.	Pumice Stone.
1901.......	43,449	25,796	2,181	24,290	334,146	2,246	4,211	8,300
1902.......	42,330	26,494	2,477	23,113	363,463	2,633	5,413	8,300
1903.......	42,443	22,126	1,930	4,735	374,975	2,486	4,577	8,300
1904.......	42,846	23,475	2,836	2,836	390,118	3,543	6,388	11,600
1905.......	39,030	19,077	5,384	5,384	389,869	6,122	9,924	11,300
1906.......	40,945	21,268	3,060	20,500	430,202	7,452	10,954	16,366
1907.......	(*d*)43,037	22,978	3,654	18,874	434,612	8,326	10,556	11,500
1908.......	46,649	26,003	2,750	17,812	425,600	7,088	10,876	15,000
1909.......	37,945	22,133	4,700	25,830	391,295	5,895	11,077	10,000
1910.......	36,840	14,495	4,200	25,700	427,274	7,069	12,149	12,900
1911.......	39,008	16,684	3,515	6,482	497,741	10,390	15,569	16,430
1912.......	41,680	21,450	2,641	*Nil*	522,088	7,479	13,792	17,386
1913.......	44,654	21,674	1,622	*Nil*	509,342	6,572	11,160	14,793
1914.......	45,538	20,464	1,649	*Nil*	431,087	5,542	11,873	14,376
1915.......	41,590	21,812	12,577	*Nil*	246,883	6,105	14,332	10,242

Year.	Pyrite (Cupriferous in Part).	Quicksilver. Ore.	Quicksilver. Metal.	Salt. Brine.	Salt. Rock.	Salt. Sea.	Silver. Ore.	Silver. Bullion. Kg
1901.......	89,376	38,614	278	10,690	23,054	401,443	511	32,464
1902.......	93,177	44,261	259	10,581	23,677	424,239	421	29,522
1903.......	101,455	55,528	312	10,962	25,911	451,633	405	24,388
1904.......	112,004	60,403	352	11,878	18,638	433,810	143	24,943
1905.......	117,667	63,378	369	12,756	19,669	405,274	170	20,215
1906.......	122,364	80,638	417	13,751	19,007	496,872	48	20,362
1907.......	126,925	76,561	434	19,238	31,540	454,454	62	20,502
1908.......	131,721	82,534	684	15,180	24,033	473,857	53	20,746
1909.......	149,084	97,592	771	15,081	28,026	421,362	44	20,534
1910.......	165,688	87,129	894	16,600	39,197	447,440	32	14,237
1911.......	165,273	97,803	955	17,251	43,763	460,439	24	12,143
1912.......	277,585	88,200	1,000	18,775	39,954	466,220	27	14,363
1913.......	317,334	109,379	1,004	17,727	41,323	585,028	*Nil*	13,094
1914.......	335,531	119,223	1,073	18,396	41,715	512,992	*Nil*	15,254
1915.......	369,320	110,642	985	17,914	33,267	382,156	*Nil*	15,362

Year.	Sulphur. Crude (Fused).	Sulphur. Ground.	Sulphur. Refined.	Talc, Ground.	Zinc. Ore.	Zinc. Spelter.
1901..........	563,096	171,252	141,431	11,770	135,784	511
1902..........	539,433	125,620	127,483	10,100	131,965	....
1903..........	553,751	139,376	139,464	6,300	157,521	126
1904..........	527,563	189,266	163,695	6,740	148,365	189
1905..........	568,927	180,676	180,774	6,626	147,834	5
1906..........	499,814	176,476	170,990	7,894	155,751	69
1907..........	426,972	151,338	160,617	8,850	160,517	188
1908..........	445,312	160,693	156,995	9,410	(*e*)152,254	(*b*)
1909..........	435,060	132,531	144,579	9,530	(*g*)130,890	(*b*)
1910..........	(*i*)430,366	171,570	169,093	11,580	(*g*)146,307	(*b*)
1911..........	414,161	158,977	166,802	14,156	139,719	(*b*)
1912..........	389,451	164,864	168,514	14,324	149,776	(*b*)
1913..........	386,310	156,103	151,713	21,350	158,278	(*b*)
1914..........	377,843	165,362	149,100	22,478	145,914	(*b*)
1915..........	358,107	140,414	116,358	21,942	80,622	(*b*)

(*a*) From *Rivista del Servizio Minerario*. (*b*) Not reported. (*c*) Includes anthracite, lignite, fossil wood, and bituminous schist. (*d*) Does not include 680 tons lead and zinc ore. (*e*) Includes 560 tons lead-zinc ore. (*g*) Includes 290 and 300 tons lead-zinc ore, 1909 and 1910. (*i*) Besides 21,297 tons ore sold. Natural.

MINERAL IMPORTS OF ITALY (a)

(In metric tons or dollars; 5 lire = $1)

Year.	Antimony.	Arsenic. Kg.	Asbestos.	Asphaltum.	Barytes.	Borax and Boric Acid.	Cement and Hydraulic Lime.	Lime.
1902.....	80	1,200	1,536	1,020	1,170	516	13,732	15,216
1903.....	98	4,400	1,691	1,567	1,099	504	15,547	10,063
1904.....	131	3,700	2,174	2,604	1,875	271	15,260	6,891
1905.....	117	3,400	1,806	3,252	1,444	112	15,797	5,556
1906.....	50	5,300	2,171	2,854	1,400	163	18,937	7,714
1907.....	163	3,100	3,110	3,661	1,540	307	29,024	6,156
1908.....	153	2,800	2,548	3,730	1,523	333	28,935	7,210
1909.....	293	4,800	2,285	3,826	2,094	386	25,250	11,120
1910.....	342	5,300	2,051	3,365	1,777	363	22,183	9.007
1911.....	358	5,500	3,892	4,238	2,024	741	24,467	7,942
1912.....	636	4,600	4,080	3,548	1,986	380	23,423	6,809
1913.....	513	2,500	4,750	4,300	1,771	159	19,950	5,501
1914.....	198	3,500	2,710	2,924	1,409	280	15,002	3,810
1915.....	825	1,700	5,380	4,139	1,319	719	5,969	2,052
1916.....	155	2,700	5,428	1,090	1,398	985	6,606	2,943

Year.	Coal. (e)	Copper, Ore.	Copper, Cement.	Copper, Brass and Bronze.	Copper and Iron Sulphates.	Gold. Kg.	Graphite.
1901......	4,838,994	11,047	1,987	8,659	32,058	494	102
1902......	5,406,069	9,422	2,299	10,865	25,107	479	60
1903......	5,546,823	9,459	649	9,588	24,566	1,396	63
1904......	5,904,578	8,104	309	15,198	37,298	1,961	52
1905......	6,437,539	6,879	486	18,188	30,684	5,768	107
1906......	7,673,435	9,363	802	21,458	25,060	4,571	361
1907......	8,300,439	18,023	888	28,937	15,939	4,443	267
1908......	8,452,320	14,784	344	28,025	25,037	(d) 8,367	383
1909......	9,303,506	11,303	630	22,391	9,137	(d) 8,311	141
1910......	9,338,752	7,550	456	30,339	13,599	(d)13,188	229
1911......	9,595,882	6,607	277	38,650	37,929	(d)12,712	246
1912......	10,057,228	6,253	578	43,729	36,602	(d)10,545	403
1913......	10,834,008	737	352	39,552	30,472	(d) 9,940	567
1914......	9,758,877	850	*Nil*	28,422	21,939	(d)10,281	162
1915......	8,369,029	571	*Nil*	54,718	14,081	(d) 6,389	1,506
1916......	8,065,041	2,453	*Nil*	68,365	6,126	(d) 343	1,071

Year.	Iron.		Iron and Steel Scrap.	Lead.		Lead Oxide and Carbonate.	Mineral Paints.
	Ore.	Pig,		Ore. (c)	Metal and Alloys in Pigs.		
1901......	4,054	159,972	148,305	9,063	2,926	815	865
1902......	4,314	155,143	198,914	1,680	7,563	846	670
1903......	5,937	126,756	206,036	689	5,398	768	859
1904......	4,390	149,130	246,359	2,187	4,541	871	940
1905......	4,745	136,077	276,311	465	6,764	686	974
1906......	6,452	168,985	344,977	4,526	10,958	984	964
1907......	22,046	231,042	362,567	4,342	9,231	953	1,119
1908......	31,090	254,239	326,119	5,620	11,742	1,474	2,616
1909......	28,150	246,730	416,354	3,003	10,011	1,132	1,713
1910......	17,673	204,854	386,604	1,426	14,674	1,225	1,775
1911......	50,554	234,770	392,703	6,042	20,187	1,077	1,756
1912......	18,606	267,355	343,728	12,391	15,627	917	1,962
1913	8,026	221,688	326,231	9,552	11,494	682	2,410
1914......	4,592	219,995	254,892	5,736	9,820	533	2,053
1915......	7,607	240,535	261,468	6,181	17,326	183	1,811
1916......	1,237	302,333	342,706	12,551	14,358	224	1,130

Year.	Nickel Alloys and Manufactures.	Petroleum.	Phosphate Rock.	Potash, Ammonia, and Caustic Soda.	Potassium Sulphate.	Quicksilver.	Silver. *Kg.*	Slag, Metalliferous.
1902.....	561	68,781	159,341	17,617	1,566	57	8,768	5,634
1903.....	525	68,220	172,328	17,528	1,353	28	12,541	8,849
1904.....	652	69,233	217,162	14,846	1,663	25	15,885	3,821
1905.....	574	66,493	240,144	17,752	1,804	57	20,697	72,785
1906.....	717	64,541	307,762	16,718	1,534	12	20,410	88,118
1907.....	725	72,715	384,896	15,225	3,866	11	21,829	5,378
1908.....	1,079	82,373	531,921	14,962	4,891	10	(*d*)83,434	1,122
1909.....	540	88,929	478,199	15,547	5,333	2.2	(*d*)47,234	878
1910.....	1,311	84,748	422,714	16,983	7,753	2.5	(*d*)55,516	3,153
1911.....	1,584	119,245	479,042	16,312	9,493	2.0	(*d*)52,576	95
1912.....	1,742	113,231	466,144	17,816	13,466	1.5	(*d*)79,763	164
1913.....	1,200	115,374	529,776	17,407	9,454	0.3	(*d*)87,856	2,560
1914.....	1,112	116,276	513,998	16,382	3,708	*Nil*	102,090(*d*)	700
1915.....	1,812	111,426	456,901	21,977	900	4.3	(*d*)83,018	1,780
1916.....	1,991	97,747	431,425	19,878	*Nil*	42.0	(*d*)50,859	1,116

Year.	Sodium Salts.		Sod. and Pot. Nitrates, Refined.	Tin.		Zinc.			
	Carbonate.	Nitrate (Crude).		Block.	Mnfrs.	Ore.	Oxide.	Spelter and Old.	Mnfrs.
1901....	21,956	40,498	315	1,858	91	23	813	3,991	4,079
1902....	26,133	24,483	314	2,114	110	131	904	3,805	4,167
1903....	24,753	43,480	638	2,288	130	46	1,416	4,551	4,461
1904....	27,747	32,283	613	2,170	150	362	1,124	5,202	4,168
1905....	29,066	46,517	689	2,304	103	14	1,246	5,997	4,701
1906....	31,170	32,508	395	3,361	167	2,042	1,920	6,835	4,421
1907....	35,538	41,457	668	2,771	183	11	1,962	8,152	5,407
1908....	38,268	60,784	428	2,602	187	7	2,026	9,339	5,112
1909....	38,252	43,658	532	2,555	191	13	1,571	9,222	4,572
1910....	45,174	61,192	1,083	2,760	238	18	2,001	8,971	5,416
1911....	45,596	59,561	417	2,524	211	428	2,100	10,742	5,892
1912....	49,284	54,634	529	2,627	157	*Nil*	2,550	11,955	5,833
1913....	52,332	67,418	574	2,973	144	5	2,983	12,448	6,071
1914....	48,115	59,850	310	2,744	110	*Nil*	2,348	10,518	4,002
1915....	53,191	71,730	2	4,245	38	*Nil*	1,833	12,843	1,087
1916....	45,212	85,649	103	2,916	32	*Nil*	1,376	17,766	1,017

MINERAL EXPORTS OF ITALY (*a*)

(In metric tons or dollars; 5 lire = $1)

Year.	Antimony.	Asbestos.	Asphaltum.	Barytes.	Borax and Boric Acid.	Cement and Hydraulic Lime.	Lime.	Coal (*e*)
1902.....	359	144	20,884	91	1,847	7,930	3,802	33,374
1903.....	314	222	24,303	35	901	6,325	4,089	29,219
1904.....	107	163	14,880	70	1,122	7,810	5,007	35,149
1905.....	132	236	23,740	162	2,255	8,445	4,194	38,555
1906.....	208	205	27,176	147	2,777	6,774	3,118	31,666
1907.....	115	142	26,036	152	1,330	4,477	3,224	40,769
1908.....	10	193	24,158	724	1,005	5,439	2,533	46,774
1909.....	8	527	21,978	125	1,704	7,534	3,525	51,343
1910.....	2	485	26,125	150	1,536	7,131	5,764	48,144
1911.....	*Nil*	517	28,455	353	1,347	10,742	9,440	40,800
1912.....	11	571	13,158	381	1,661	55,091	6,736	26,298
1913.....	*Nil*	672	6,645	234	1,373	55,908	5,161	192,002
1914.....	51	509	6,367	210	1,195	40,880	5,161	54,908
1915	3	148	6,720	3,288	1,702	40,430	627	79,090
1916.....	188	259	4,103	2,755	2,098	42,425	114	94,319

Year.	Copper, Ore.	Copper and Iron Sulphate.	Gold. *Kg.*	Graphite.	Iron.		
					Ore.	Pig.	Scrap.
1901...........	9	20	2,955	7,169	121,592	311	....
1902...........	11	39	733	7,098	209,070	395	....
1903...........	15	44	1,291	7,068	98,319	810	....
1904...........	43	29	1,494	7,433	2,577	229	....
1905...........	77	249	1,731	6,811	11,358	1,395	....
1906...........	189	102	1,476	4,904	1,833	254	....
1907...........	179	835	802	7,474	26,000	121	....
1908...........	188	721	7,588	7,009	35,653	176	1,676
1909...........	233	1,211	15,452	8,125	46	209	1,480
1910...........	969	741	16,643	7,647	9,892	327	2,450
1911...........	130	157	14,144	7,633	22,851	290	3,390
1912...........	267	1,445	13,993	7,785	12,313	51	5,662
1913...........	285	609	16,440	8,329	9,660	555	6,895
1914...........	78	1,856	6,724	7,589	8,944	69	4,636
1915...........	2	62	1,072	6,508	157	40	2,576
1916...........	*Nil*	170	632	5,615	30	2	13

Year.	Lead.			Mineral Paints.	Phosphate Rock.	Quicksilver.	Salt.	Silver. *Kg.*
	Ore.	Lead Alloys, in Pigs.	Oxide and Carbonate.					
1901.....	3,977	4,463	410	2,913	1,290	301	114,210	42,325
1902.....	3,354	5,650	404	2,953	894	215	145,190	20,427
1903.....	5,041	2,911	426	3,305	2,942	222	144,910	9,486
1904.....	5,524	1,954	347	3,231	2,812	266	130,940	24,165
1905.....	4,311	976	310	3,632	3,519	243	116,040	25,947
1906.....	8,356	2,005	315	4,502	1,652	278	126,199	18,262
1907.....	3,213	1,548	240	4,602	4,560	350	99,191	18,164
1908.....	2,041	1,243	219	3,446	2,271	565	85,489	(*d*)28,716
1909.....	1,037	782	211	4,310	2,979	714	103,895	(*d*)87,653
1910.....	4,122	933	197	3,945	3,627	781	122,404	(*d*)22,403
1911.....	15,791	637	196	4,182	5,427	1,037	119,173	(*d*)28,434
1912.....	17,062	4,122	75	4,417	1,285	993	155,543	(*d*)28,275
1913....	16,950	577	314	4,166	14,171	993	161,118	(*d*)18,786
1914....	15,403	189	687	4,220	8,569	760	124,860	(*d*)12,233
1915.....	3,817	14	339	3,458	1,809	853	108,991	(*d*)28,016
1916.....	9,871	4	1,582	2,766	*Nil*	767	31,135	(*d*) 4,898

Year.	Slag.	Sodium Salts.			Sulphur.	Tin.		Zinc.		
		Carbonate	Nitrate (Crude).	Sod. and Pot. Nitrates, Refined.		Block.	Manufactures	Ore.	Oxide.	Spelter and Scrap.
1901....	3,261	377	116	59	414,018	202	187	103,020	140	349
1902....	3,615	446	346	259	439,242	236	174	114,894	122	338
1903....	4,929	482	781	492	461,289	173	180	116,449	116	591
1904....	4,458	376	363	230	437,067	171	151	126,393	483	263
1905....	9,844	214	424	159	381,128	285	107	117,810	173	434
1906....	8,990	253	80	133	336,339	303	81	144,244	687	639
1907....	10,934	200	138	102	297,378	434	117	142,271	727	1,182
1908....	12,122	583	37	57	330,093	180	173	122,456	395	984
1909....	17,163	517	464	163	329,233	85	126	123,936	212	983
1910....	10,488	321	98	45	344,513	164	245	127,315	957	845
1911....	8,274	180	168	15	398,592	166	319	133,471	1,577	616
1912....	19,563	243	27	7	376,387	83	359	152,840	2,165	1,222
1913....	8,251	337	50	10	351,339	152	394	144,644	1,313	1,566
1914....	7,822	123	179	12	259,920	179	313	89,776	1,219	1,234
1915....	715	94	*Nil*	5	293,908	36	364	59,734	2,560	86
1916....	495	31	*Nil*	108	326,435	100	388	80,180	1,294	129

(*a*) From ***Statistica del Commercio speciale di Importazione e di Esportazione.*** (*b*) Not reported. (*c*) Includes argentiferous lead ore. (*d*) Includes coin, bullion, sheets, leaf, and partly manufactured silver (*e*) Includes coke.

JAPAN

The total mineral production of the Japanese Empire, according to the latest available returns, is shown in the following table, in metric tons, unless otherwise specified. Figures in full-faced type are either provisional figures or estimates.

MINERAL PRODUCTION OF JAPAN (*a*)

Year.	Antimony.		Arsenic. *Kg.*	Coal.	Copper.	Gold. *Kg.*	Graphite	Pig. Iron.	Lead.
	Ore.	Metal.							
1901....	118	429	10,312	8,884,812	27,392	2,475	88	29,449	1,803
1902....	88	528	12,188	9,588,910	29,034	2,975	97	32,130	1,644
1903....	153	434	6,000	10,088,845	33,245	3,140	114	33,870	1,728
1904....	104	321	4,000	10,723,796	33,187	2,765	216	38,143	1,803
1905....	96	190	8,333	11,955,946	35,944	3,048	209	53,210	2,272
1906....	97	627	5,250	13,468,529	36,963	2,873	177	57,373	4,305
1907....	(*b*)	248	7,491	13,764,731	40,183	2,938	103	44,447	3,079
1908....	(*b*)	198	19,838	14,767,638	41,399	3,598	177	42,007	2,910
1909....	10	157	8,061	14,810,412	45,117	3,932	121	46,627	3,337
1910(*d*)	8	120	11,463	15,433,621	48,545	4,368	145	58,043	3,845
1911(*d*)	....	97	5,760	17,632,710	53,401	4,690	114	63,986	4,125
1912....	....	80	....	19,515,285	62,939	5,233	149	56,265	3,764
1913....	....	(*d*)21	....	21,664,764	66,537	4,666	(*d*)665	57,513	3,779
1914...	....	3,865	....	22,296,738	70,481	7,068	574	73,909	4,563
1915....	8,390	8,347	14,885	20,490,702	75,415	8,293	666	64,897	4,764
1916....	12,402	**12,398**	....	20,130,740	81,280	7,446	....	65,014	....

Year.	Manganese Ore.	Petroleum. *Gallons.*	Phosphates.	Pyrite.	Quicksilver. *Kg.*	Salt. *Hectoliters.*	Silver. *Kg.*	Sulphur.	Tin.
1901....	16,270	30,470,068	(*b*)	17,589	750	12,463,771	54,739	16,548	14.1
1902....	10,844	39,056,820	196	18,580	1,418	11,042,192	57,635	18,287	18.6
1903....	5,616	34,850,129	191	16,149	206	6,574,890	58,704	22,914	19.0
1904....	4,324	50,724,174	13	24,886	*Nil.*	7,019,650	61,339	25,587	25.0
1905....	14,017	51,573,754	1,519	25,569	349	(*b*)	82,886	24,652	26.0
1906....	54,339	47,132,800	3,037	36,038	336	(*b*)	76,247	27,589	77.0
1907....	20,586	60,005,957	1,721	56,166	456	(*f*)636,168	95,600	33,329	31.8
1908....	11,130	60,110,558	740	33,867	804	(*f*)659,202	123,180	33,149	25.7
1909(*d*) .	8,708	65,165,860	3,781	27,066	335	(*f*)696,049	127,917	36,317	22.8
1910(*d*) .	11,120	65,789,858	1,042	78,418	407	(*f*)696,474	141,613	43,155	23.0
1911....	9,787	63,843,601	2,271	73,879	1,021	(*g*)567,715	138,287	50,274	24.8
1912....	12,060	72,839,260	7,847	74,929	27	....	152,385	55,005	35.6
1913....	2,313	67,557,322	19,047	114,589	....	....	146,180	59,481	379.0
1914....	17,076	112,163,530	38,252	115,840	....	....	150,958	59,850	245.0
1915....	25,870	124,277,191	57,723	67,536	38	....	159,261	61,405	341.0
1916....	....	120,111,856	....	....	....	....	172,194	92,677	**255.0**

(*a*) From *Résumé Statistique de l'Empire du Japan*, Tokio. (*b*) Not reported. (*d*) From reports of the Japanese Department of Agriculture and Commerce. (*f*) Metric tons including Taiwan, fiscal years. (*g*) Metric tons; from *Résumé Statistique de l'Empire du Japan.*

MEXICO

Owing to the incompleteness of the Mexican statistics of production, we are unable to give any satisfactory table. Exports may, however, be taken as indicating the condition of the mining industry. We owe the statistics for 1908, 1909, and 1910, together with a complete revision of this table, to the courtesy of Don Miguel M. Irigoyen, chief of the Section of Statistics, Secretaria de Hacienda y Credito Publico.

MINERAL EXPORTS OF MEXICO (*a*)
(In metric tons or Mexican dollars)

Year.	Antimony.		Coal.	Copper.		Gold.				
	Metal.	Ore.		Ore.	Ingot.	Ore.	Bullion.	Specie.	Cyanide.	Sulphide.
1898...	......	5,932	118,553	13,146	10,362	$1,037,202	$6,493,735	$367,704	$294,730	$64,061
1899...	......	10,382	113,192	223	25,293	335,849	7,017,286	183,474	115,961	266,782
1900...	......	2,313	38,676	408	27,970	306,392	7,435,864	192,456	128,675	177,193
1901...	......	5,103	17,281	5,576	33,818	284,722	8,324,681	210,431	178,803	81,744
1902...	1,218	1,280	3,406	6,101	63,609	303,979	9,079,371	129,899	78,295	40,658
1903 (*c*)	2,304	7,302	1,840	10,912	51,716	264,503	9,693,692	54,636	85,465	124,020
1904...	1,694	81	125	48,365	57,338	537,290	10,867,272	172,532	79,129	176,090
1905...	1,978	57	497	92,540	56,634	1,513,344	29,636,117	106,470	397,814	138,033
1906...	2,418	178	91	73,193	46,767	5,369,173	21,072,014	37,746	337,294	180,348
1907...	4,615	681	1,532	115,245	51,519	3,033,090	19,653,362	5,023,404	417,162	497,893
1908...	4,046	36	719	70,900	26,214	2,746,289	30,101,546	42,389	144,959	334,944
1909...	4,115	31	235	136,031	32,580	2,346,279	40,725,976	23,678	85,110	250,741
1910...	3,730	6	120	129,568	54,061	2,526,444	46,189,613	37,723	46,803	168,162
1911...	4,131	121	101	109,627	60,493	1,945,660	48,113,427	8,153,293	38,031	141,640
1912...	3,491	15	50,777	103,129	60,439	1,121,333	42,686,667	1,479,292	43,481	119,357
1913...	2,340	(*b*)	40	19,500	29,438	785,531	32,918,172	470,758	54,417	172,188

Year.	Graphite.	Gypsum.	Lead.		Silver.					
			Ore.	Base Bullion.	Ore.	Bullion.	Specie.	Sulphide.	Cyanide.	Slag.
1898...	1,365	1,650	(*b*)	60,918	$11,048,358	$37,137,599	$16,588,789	$1,663,501	$257,342	$46,488
1899...	2,305	1,050	1	67,441	10,766,099	37,585,911	5,580,834	1,929,085	76,942	4,819
1900...	2,561	1,600	468	74,944	12,495,524	41,468,745	22,679,655	1,893,646	67,607	87,880
1901...	762	800	(*b*)	79,097	9,615,939	36,348,374	12,038,158	2,141,685	259,282	93,543
1902...	1,434	(*b*)	118	107,366	4,108,088	45,796,576	17,753,526	1,978,919	108,344	132,093
1903 (*c*)	1,404	(*b*)	11	100,532	11,781,048	48,276,797	16,167,673	1,642,627	135,561	289,900
1904...	970	(*b*)	1	95,010	11,000,869	45,430,020	7,251,132	1,392,356	171,452	202,594
1905...	970	27	1	101,196	8,505,834	63,564,789	20,335,297	736,228	438,094	29,012
1906...	3,915	(*b*)	(*b*)	73,699	9,619,763	63,057,152	42,390,357	595,112	434,885	(*b*)
1907...	3,202	(*b*)	11	76,158	11,396,844	68,187,169	23,848,571	785,116	483,638	(*b*)
1908...	1,076	(*b*)	26	127,010	11,230,372	63,298,659	60,405	791,698	68,849	(*b*)
1909...	1,704	(*b*)	1	118,186	8,057,189	66,789,716	91,006	557,520	78,688	(*b*)
1910...	2,332	1	355	120,662	6,793,896	70,272,894	72,891	208,300	52,053	(*b*)
1911...	2,974	(*b*)	397	124,605	6,766,644	78,515,378	8,901	235,410	159,170	*Nil*
1912...	2,865	(*b*)	59	109,717	5,769,575	82,047,500	8,645	(*d*)	347,277	*Nil*
1913...	1,057	(*b*)	1,386	55,530	2,108,805	63,232,843	2,585,701	423,625	418,522	(*b*)

(*a*) From the *Estadistica Fiscal.* The figures for the calendar years were arrived at by combining those of the successive semesters of the different fiscal years. (*b*) Not reported. (*c*) Figures for 1904 are from *Anuario Estadistico de la República Mexicana* for 1904. (*d*) 11 metric tons.

NORWAY

The official statistics of mineral production, imports and exports are summarized in the following tables:

MINERAL PRODUCTION OF NORWAY (*a*)

(In metric tons or dollars; 1 Krone = 27 cents)

Year.	Apatite. (*b*)	Chrome Ore.	Copper.		Feldspar.	Gold.	Iron.		
			Ore.	Ingot.			Ore.	Pig and Cast.	Bars and Steel.
1903 ...	1,795	*Nil.*	35,417	1,382	18,590	$8,370	53,475	509	442
1904 ...	1,456	154	36,891	1,342	20,835	*Nil.*	45,328	350	395
1905. ..	2,522	*Nil.*	37,045	1,153	22,508	*Nil.*	46,582	474	253
1906 ...	3,482	*Nil.*	32,203	1,333	23,896	5,400	109,259	257	317
1907. ..	1,830	107	39,887	1,517	32,970	*Nil.*	140,804	*Nil.*	283
1908 ...	1,771	*Nil.*	33,688	1,806	34,437	*Nil.*	119,656	....	....
1909 ...	1,364	*Nil.*	42,612	1,594	36,439	8,000	40,389	....	....
1910 ...	703	....	46,308	1,814	39,507	5,000	102,447	....	....
1911 ...	897	....	34,705	1,650	34,864	....	220,524	316	....
1912 ...	1,168	115	60,018	2,130	39,844	....	408,092	309	....
1913 ...	757	....	70,349	2,741	40,842	....	544,686	346	....
1914 ...	750	81	57,951	2,860	27,967	....	652,273	6,909	....
1915 ...	1,901	350	56,097	2,828	8,778	....	714,917	8,741	....

Year.	Molybdenite.	Nickel.		Pyrite, Iron, and Copper.	Rutile.	Silver.		Zinc Ore. (*c*)
		Ore.	Metal.			Ore and Native Silver.	Metal. *Kg.*	
1903.....	31	5,670	60	129,939	25	481	7,269	335
1904.....	30	5,352	75	133,603	25	1,297	8,064	42
1905.....	46	5,477	73	162,012	35	1,570	7,100	4,241
1906.....	1,026	6,081	77	197,886	55	1,565	6,370	3,308
1907.....	30	5,781	81	236,038	55	1,756	6,700	400
1908.....	35	5,190	81	269,129	83	2,262	7,470	2,435
1909.....	30	5,770	62	282,606	....	2,729	7,780	983
1910.....	....	19,639	69.8	329,642	116	....	....	2,219
1911.....	....	27,743	172	369,055	76	2,892	7,635	2,240
1912.....	21	30,697	390	464,326	100	4,027	8,400	40
1913.....	12	49,990	690	441,291	77	5,411	9,400	897
1914.....	(*d*)83	48,529	794	414,886	30	7,372	12,904	243
1915.....	(*d*)97	77,018	892	513,335	170	8,431	11,900	1,829

(*a*) *Tabeller vedkommende Norges Bergværkdsdrift,* and *Statistisk Aarbok for Kongeriket Norge*
(*b*) Exports which represent production. (*c*) Includes lead ore. (*d*) Includes wolframite.

MINERAL IMPORTS OF NORWAY (a)

(In metric tons)

Year.	Borax. *Kg.*	Cement and Hydraulic Lime.	Coke, Coal, and Cinders. *Hectoliters.*	Copper and Brass.		Iron and Steel.	
				Plates and Bars.	Wares.	Pig.	Bars, Hoops, etc. Wrought Iron.
1902.......	(c)	18,984	19,338,615	1,118	(c)	18,969	26,685
1903.......	(c)	17,906	20,086,974	899	309	20,652	21,977
1904.......	54,953	12,845	21,049,128	688	866	18,891	24,094
1905.......	(c)	13,797	20,973,608	882	1,146	20,828	27,740
1906.......	63,000	11,676	21,478,000	906	783	20,197	26,015
1907.......	79,810	16,647	24,274,260	(f) 954	1,107	23,345	32,764
1908.......	87,255	44,991	(e)2,073,907	(f)1,013	1,157	26,106	31,849
1909	79,786	57,768	(e)2,095,611	(f) 869	1,095	23,167	31,215
1910.......	105,453	20,100	(e)2,159,717	(f)1,118	1,406	28,034	34,623
1911.......	100,493	17,892	(e)2,187,246	(f)1,229	1,780	26,569	36,172
1912.......	103,923	27,960	(e)2,474,253	(f)1,567	2,116	29,908	44,756
1913.......	107,633	31,989	(e)2,482,424	(f)1,769	2,035	30,682	49,442
1914.......	....	40,762	(e)2,749,250	3,471	2,026	32,199	44,848

Year.	Iron and Steel *Continued.*						Lead in Pigs and Sheets.
	Anchors, Cables, and Chains.	Rails.	Nails, Spikes, and Screws.	Steel.	Sheets and Plates.	Other Manufactures.	
1902	2,103	15,316	2,205	1,754	36,288	22,069	(c)
1903	1,807	4,631	1,261	1,958	42,098	18,855	311
1904	2,109	5,814	1,071	1,610	42,013	5,462	498
1905	2,224	6,566	1,222	1,436	42,203	44,414	448
1906.....	2,585	8,086	1,012	2,018	48,969	45,959	727
907	2,653	6,989	991	1,592	47,758	48,965	887
1908	2,535	12,180	1,032	1,628	49,569	52,594	529
1909	1,750	9,051	1,049	1,911	46,195	55,198	536
1910	2,131	5,512	852	3,203	56,898	60,282	838
1911	2,327	15,312	1,129	3,908	65,847	72,170	939
1912	2,591	12,276	1,313	4,239	84,525	86,552	1,142
1913	2,479	15.291	....	3,197	76,158	86,411	1,054
1914	2,651	21,834	....	2,739	73,006	98,928	1,079

Year.	Lead-white and Zinc Oxide.	Petroleum and Paraffin.	Potash.	Salt.	Salt-peter.	Soda.	Sulphur. (b)	Tin in Blocks, etc.	Zinc in Bars, Plates, etc.
1902 ...	(c)	(c)	(c)	141,415	315	(c)	(c)	(c)	1,104
1903 ...	(c)	58,822	457	143,110	245	4,200	8,829	106	1,015
1904 ...	1,898	50,543	477	153,699	321	3,197	12,181	176	940
1905 ...	1,309	43,860	393	137,800	1,048	3,704	10,240	134	967
1906 ...	1,149	41,546	396	167,300	776	4,334	11,465	261	2,791
1907 ...	1,245	44,231	588	163,458	1,004	5,819	11,412	332	3,549
1908 ...	1,201	64,680	504	177,349	935	7,850	12,281	323	1,418
1909 ...	1,304	63,042	475	164,195	572	8,357	10,293	280	1,336
1910 ...	1,277	63,976	536	182,288	546	9,270	10,279	358	5,891
1911 ...	1,465	71,496	524	192,354	786	9,566	8,782	353	9,173
1912 ...	1,864	80,023	541	214,817	418	15,877	13,911	439	9,636
1913 ...	2,502	79,253	572	214,987	522	16,255	15,411	333	13,560
1914 ..	2,288	89,692	907	201,255	141	20,275	10,448	696	17,487

MINERAL EXPORTS OF NORWAY (*a*)
(In metric tons)

Year.	Apatite.	Copper.			Feldspar.	Iodine. *Kg.*	Iron.
		Ore.	Ingot.	Scrap.			Ore.
1902	2,295	4,848	1,913	(*c*)	(*d*)19,611	....	48,775
1903	1,795	3,448	1,930	888	(*d*)18,640	11,417	41,575
1904	1,456	2,673	1,124	785	20,835	9,414	45,434
1905	2,522	3,393	958	968	20,696	12,000	60,558
1906	3,482	84	875	964	19,669	13,248	81,398
1907	1,830	1,581	1,033	1,644	29,399	13,780	132,593
1908	1,771	156	1,260	385	29,896	11,097	110,425
1909	1,365	3,245	1,335	543	33,692	13,620	38,933
1910	703	241	1,377	583	39,507	13,114	88,715
1911	500	924	1,091	575	34,864	16,982	180,932
1912	....	423	1,551	366	39,844	11,642	404,990
1913	....	74	2,644	167	40,843	12,149	568,763
1914	....	0.1	2,345	676	27,703	2,320	456,925

Year.	Iron (*Continued*).				Nickel Ore.	Pyrite.	Zinc.
	Pig and Scrap.	Bars and Hoops.	Nails and Spikes.	Steel.			
1902	7,359	166	6,431	240	1	105,980	....
1903	6,350	10	6,504	200	*Nil.*	118,148	....
1904	10,152	13	7,477	167	30	116,550	....
1905	9,920	34	8,725	88	220	147,155	....
1906	7,362	8	6,786	21	*Nil.*	164,119	....
1907	4,652	7	5,879	31	11	187,983	....
1908	6,787	2	4,839	17	*Nil.*	218,851	....
1909	11,429	24	5,187	11	3	216,767	....
1910	13,455	5	6,878	34	....	343,073	....
1911	12,569	40	5,692	271	(*g*)385	343,850	....
1912	16,889	....	5,326	296	(*g*)594	424,121	....
1913	26,917	....	3,972	150	....	460,912	10,538
1914	14,498	....	3,804	1,274	(*g*)646	400,996	16,428

(a) From *Tabeller vedkommende Norges Bergvaerksdrift* and *Tabeller vedkommende Norges Handel.* (*b*) Includes flowers of sulphur. (*c*) Returns not available. (*d*) Includes a small quantity of fluorspar. (*f*) Includes a quantity of sheet aluminium. (*g*) Metallic nickel.

PORTUGAL

The subjoined table reports the mineral production of Portugal:

MINERAL PRODUCTION OF PORTUGAL (*a*)
(In metric tons)

Year.	Antimony Ore.	Arsenic Ore.	Coal (Anthracite). (*c*)	Copper.			
				Copper-Iron Pyrite. (*e*)	Other Ores.	Cement.	Matte.
1901	(*b*)	527	16,000	443,397	(*b*)	2,061	(*b*)
1902	68	736	11,000	413,714	655	2,205	(*b*)
1903	83	698	8,063	376,177	527	2,448	(*b*)
1904	31	1,370	12,805	383,581	297	(*b*)	(*b*)
1905	84	1,562	11,449	352,479	210	2,148	(*b*)
1906	481	1,322	6,762	350,746	196	3,634	(*b*)
1907	383	1,538	8,824	241,771	2,478	2,942	298
1908	76	1,655	4,614	81,417	15,455	3,041	564
1909	6	1,420	6,274	12,337	1,321	3,037	309
1910	25	974	8,149	19,161	230	3,768	230
1911	....	887	10,610	15,287	517	3,979	283
1912	100	1,006	15,626	120,148	1,309	4,028	....
1913	19	925	25,037	13,550	....	4,177	....
1914	*Nil.*	960	29,680	40,850	219,140	3,200	....

Year.	Gold. *Kg.*	Iron Ore.	Lead Ore (Galena).	Manganese Ore.	Sulphur Ore.	Tin Ore and Metal.	Tungsten Ore.
1901	2.0	21,599	445	904	(*e*)	31	90
1902	2.0	19,914	1,651	(*b*)	(*e*)	24	234
1903	1.3	15,200	830	30	(*e*)	(*b*)	228
1904	*Nil.*	12,488	291	(*b*)	(*e*)	51	290
1905	*Nil.*	3,200	50	(*b*)	(*e*)	20	358
1906	*Nil.*	(*b*)	511	22	(*e*)	22	570
1907	10.5	(*b*)	510	1,374	123,393	35	226
1908	57.0	(*b*)	481	(*b*)	24,522	28	106
1909	25.0	(*b*)	736	(*b*)	272,398	18	673
1910	4.1	3,360	919	(*b*)	293,745	9	948
1911	3.6	19,541	1,185	6	267,486	86	903
1912	3.5	35,210	495	6	481,295	173	1,227
1913	1.0	49,182	1,046	(*b*)	377,533	254	1,039
1914	*Nil.*	6,639	2,163	(*b*)	32,554	370	615

(*a*) From reports specially furnished *The Mineral Industry* by the Chief of the Department of Mines of the Ministerio das Obras Publicas, except for 1904 to 1906, inclusive, and 1913 and 1914, which are from official Government reports. The mineral production of the country is identical with exports, except in the case of coal. (*b*) Not reported. (*c*) Consumed in the country. (*e*) Previous to 1907 the figures for "Sulphur Ore" (largely pyrite) were included under "Copper-Iron Pyrite."

RHODESIA

The statistics of the mineral production of Rhodesia for the last 12 years are given in the accompanying table.

MINERAL AND METALLURGICAL PRODUCTION OF RHODESIA (*a*)

Year.	Gold. *Oz.*	Value.	Silver. *Oz.*	Lead. *Tons.* (*b*)	Coal. *Tons.* (*b*)	Year.	Gold. *Oz.*	Value.	Silver. *Oz.*	Lead. *Tons.* (*b*)	Coal. *Tons.* (*b*)
1905..	407,048	$7,046,692	89,278	570	97,191	1911..	628,521	$12,991,500	187,641	639	212,529
1906..	551,894	9,647,581	110,575	652	103,803	1912..	642,807	13,174,058	176,532	587	216,140
1907..	612,052	10,589,385	147,324	756	115,073	1913..	689,954	14,261,343	142,390	327	243,328
1908..	606,962	12,276,394	283,424	1,069	164,114	1914..	854,480	17,423,087	150,793	168	349,459
1909..	623,388	12,985,430	262,133	965	170,893	1915..	915,029	18,603,973	186,233	28	409,763
1910..	609,956	12,657,791	217,633	749	180,068	1916..	930,356	19,321,155	200,676	......	491,582

(*a*) From report of Colonel Seely, Under-Secretary of State for the colonies. (*b*) Short tons.

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RUSSIA

The mineral and metallurgical production of Russia, according to the best statistics available to Mineral Industry, is given in the subjoined tables.

MINERAL AND METALLURGICAL PRODUCTION OF RUSSIA (*a*)

(In metric tons; 1 metric ton = 61.05 poods)

Year.	Asbestos.	Chrome Ore.	Coal.	Copper.	Gold. (*b*)	Pig Iron.	Lead.	Manganese Ore.
1901..	4,398	22,169	16,526,652	8,467	$22,763,967	2,866,779	156.0	522,395
1902..	4,508	19,656	16,465,852	8,817	22,258,343	2,598,086	225.3	536,519
1903..	5,264	16,421	17,868,515	9,232	24,147,222	2,487,783	106.3	414,334
1904..	7,502	26,575	19,608,631	9,835	24,627,537	2,972,115	90.3	430,090
1905..	5,896	27,051	18,727,766	8,515	20,521,587	2,628,101	700.2	508,635
1906..	9,197	16,969	21,593,158	9,296	20,020,862	2,694,895	906.8	1,015,686
1907..	9,398	(*g*)26,357	25,741,321	15,930	26,518,253	3,041,570	520.0	(*g*)1,003,528
1908..	10,911	(*g*)10,950	(*g*)25,903,560	17,118	33,143,810	2,818,450	522.5	362,308
1909..	(*h*)13,129	22,213	24,532,349	19,656	31,889,956	2,889,353	.....	574,938
1910..	(*h*)10,936	1,362	(*f*)23,105,628	(*f*)22,619	(*f*) 35,566,045	(*f*)3,042,046	.....	668,050
1911..	17,071	1,238	28,007,239	(*f*)25,097	(*f*) 34,550,609	3,593,000	.....	(*i*) 636,180
1912..	18,138	21,277	30,641,163	33,513	28,852,881	3,726,000	.....	903,226
1913..	18,594	....	32,206,000	34,282	22,199,000	3,801,273	.....	1,130,000
1914..	....	....	....	32,250	24,300,000	....	.....	652,354
1915..	....	....	....	35,470	....	**3,792,516**	.....	....
1916.	....	....	....	....	....	3,861,600	.....	....

Year.	Petroleum.	Phosphate Rock.	Platinum. *Kg.*	Pyrite.	Quicksilver.	Salt.	Silver. *Kg.*	Sulphur.	Zinc.
1900..	9,844,390	25,663	5,089	23,154	141	1,968,007	2,293	1,587	5,963
1901..	10,925,471	21,276	6,371	30,732	363	1,705,924	1,088	2,489	6,104
1902..	10,445,536	13,709	6,135	26,465	416	1,847,021	1,200	1,800	8,264
1903..	9,759,214	14,635	6,009	22,780	362	1,658,938	1,152	281	9,894
1904..	10,058,968	20,282	5,016	31,667	332	1,908,275	726	16	10,612
1905..	7,505,637	20,585	5,250	30,689	318	1,844,678	2,965	16	7,911
1906..	8,167,934	18,970	5,776	20,660	210	1,730,934	430	39	9,602
1907..	9,098,931	(*g*)15,457	5,903	18,316	(*g*)132	1,873,171	7,843	(*d*)57	10,409
1908..	8,732,301	(*g*)14,976	4,883	56,345	147	1,879,717	9,595	(*d*)85	9,960
1909..	8,961,507	(*h*)21,326	5,120	(*j*)46,078	....	2,259,690	(*h*)15,415	....	7,644
1910..	8,952,793	(*h*)24,883	5,471	(*j*)55,980	....	2,047,980	(*h*)14,841	....	(*f*)8,631
1911..	9,152,315	(*h*)25,503	(*f*)5,432	113,054	....	2,013,765	15,512	....	(*f*)9,652
1912..	9,249,600	....	5,523	123,990	....	....	....	....	8,763
1913..	9,474,876	....	4,897	....	....	....	....	....	7,610
1914..	9,099,494	....	4,880	....	....	....	....	....	....
1915..	....	....	3,374	....	....	....	....	....	....

(*a*) From official sources. (*b*) The value of gold is taken at $20.67 per ounce. (*d*) Includes sulphide ore. (*f*) Statistics of Association of Russian Manufacturers and Traders. (*g*) St. Petersburg Scientific Committee. (*h*) The Russian Year Book, Dr. Kennard, London. (*i*) Exports. (*j*) *Mineral Resources of U. S.*

SOUTH AMERICA

The following tables itemize the statistics of the production and the foreign commerce, or both, of mineral and metallurgical products of South American countries so far as available. No statistics later than those given in the tables have been published. Figures in full-faced type are either provisional figures or estimates.

MINERAL AND METAL PRODUCTION OF BOLIVIA (*a*)

(In metric tons)

Year.	Antimony Ore.	Bismuth.		Copper Ore.	Copper. (*c*)	Gold. (*b*)	Silver. (*d*)	Tin Ore.	Tungsten Ore.
		Metal.	Ore.						
1907....	2,279	249	153.379	....	3,469	$3,551	3,696	27,668	(*e*)500
1908....	734	259	160.305	....	3,027	21,617	156.5	29,938	170
1909....	....	89	236.762	....	3,097	....	155.4	35,566	170
1910....	....	97	311.060	....	3,212	....	143	38,548	207
1911....	312	(*g*)415	1,208.689	....	2,950	22,313	128.0	37,073	297
1912....	91	(*g*)478	....	....	4,707	23,038	123.9	38,614	472
1913....	62	391	32	....	4,020	**175,000**	81.3	44,597	283
1914....	186	(*g*)437	....	4,793	3,874	....	72	37,259	276
1915....	17,923	(*g*)663	....	17,945	5,868	....	78	36,492	793

(*a*) From a British Consular report and Revista de Aduanas. (*b*) Reduced to U. S. currency. (*c*) Includes ingots, precipitate, matte and concentrate. (*d*) Includes ingots, ore, and sulphide. (*e*) U. S. Geol. Surv. (*g*) Metal and metal content of ore.

MINERAL EXPORTS OF BRAZIL (*a*)

(In metric tons or dollars) (*d*)

Year.	Agate.	Carbonado. *Carats*	Copper Ore. *Carats.*	Diamonds. *Carats.*	Gold.	Manganese Ore.	Mica and Talc.	Monazite.	Platinum *Grams.*	Precious Stones. (*b*)	Rock Crystal.
1908(*e*)	79	126,380	(*c*)	97,090	$2,187,950	166,122	$5,540	4,965	*Nil*	$109,150	36
1909(*e*)	......	177,572	(*c*)	58,862	2,252,900	240,774	.....	6,462	*Nil*	56,338	....
1910(*e*)	34	13,848	(*c*)	14,366	1,954,674	253,953	.....	5,437	*Nil*	745	....
1911(*e*)	112	63,400	1	103,567	2,850,370	173,941	9	371	*Nil*	135,220	24
1912(*e*)	103	47,998	....	139,175	2,676,950	154,870	11.5	3,398	*Nil*	74,597	45
1913..	......	....	....	....	2,692,154	122,300	......	1,437	......	174,066	....
1914..	......	....	....	....	2,127,515	183,600	......	600	......	21,022	....
1915..	......	....	....	....	2,390,719	288,671	......	439	......	44,024	....
1916..	......	....	....	....	....	503,130	......	......	......	....	....

(*a*) As reported by the *Brazilian Review*. (*b*) Other than carbonado and diamonds. (*c*) Statistics not available. (*d*) The par exchange value of the *Mil Reis* in 1907 was $0.546 U.S. gold. Common exchange value was in 1902, $4.155; in 1903, $4.134; in 1904, $4.146; in 1905, $3.153; in 1906, $3.103, and in 1907, $3.301. (*e*) Reported by U. S. Consul at Rio de Janeiro.

MINERAL PRODUCTION OF CHILE (*a*)
(In metric tons)

Year.	Borax.	Coal.	Iron Ore.	Copper.	Gold. *Kg.*	Guano.	Iodine.	Salt.	Silver. *Kg.*	Sodium Nitrate.	Sulphur.
1903..	16,879	827,112	....	29,923	994	11,134	387	16,264	28,552	1,444,920	3,560
1904..	16,733	751,628	....	31,025	1,135	2,669	461	17,674	28,501	1,487,598	3,594
1905..	19,612	793,927	....	29,126	1,055	19,380	564	12,108	16,315	1,669,806	3,470
1906..	28,996	932,488	....	25,829	1,135	4,709	331	17,116	12,211	1,822,144	4,598
1907..	28,374	832,612	....	28,863	1,907	7,518	4,202	18,982	18,736	1,846,036	2,905
1908..	35,039	939,836	....	42,097	1,189	871	330	16,257	43,569	1,970,974	2,705
1909..	32,218	898,971	....	42,726	1,268	10,692	474	20,463	35,907	2,110,961	4,508
1910..	35,192	1,074,174	....	38,232	1,088	12,683	581	23,361	34,958	2,465,415	3,823
1911..	45,558	1,188,053	....	36,420	437	17,841	437	23,720	27,675	2,521,023	4,451
1912..	43,356	1,334,407	....	41,647	1,101	18,266	458	17,045	30,178	2,585,850	4,431
1913(*e*)	**50,225**	**1,283,450**	**14,100**	42,264	**1,147**	......	**437**	....	39,564	2,666,835	**6,647**
1914(*e*)	34,203	266,962	63,505	45,682	**1,017**	......	489	....	**36,581**	1,846,783	**10,008**
1915(*e*)	....	....	....	52,081	......	......	......	......	....	2,023,562	......
1916(*e*)	....	....	....	71,430	......	......	......	......	....	....	......

(*a*) From *Estadistica Minera de Chile.* (*b*) The combined output of the years 1894 to 1902, inclusive was 86,892 tons.. (*c*) The combined output of Chile up to the end of 1902 is estimated at 20,650,000 tons. (*e*) Exports. (*f*) The combined output of Chile up to the end of 1902 is estimated at 163,704 tons, valued at 5,041.560 pesos ($1,840,169).

MINERAL AND METAL PRODUCTION OF PERU (*a*)
(In metric tons)

Year.	Bismuth.	Borate.	Coal. (*b*)	Copper.	Gold. *Kg.*	Lead.	Petroleum.	Quicksilver. *Kg.*	Silver. *Kg.*	Salt.	Tungsten Ore.	Vanadium Ore.
1909...	30	2,715	321,502	26,068	554.0	2,093	188,128	350	207,656	22,715	......	....
1910...	24	2,351	307,320	27,347	708.0	1,866	167,712	350	252,565	17,594	12	....
1911...	24	1,923	324,000	27,735	741.2	2,208	195,276	560	289,383	24,867	48	....
1912...	51	1,674	278,927	26,970	1,435.0	4,050	233,600	400	324,352	23,292	195	....
1913...	25	2,001	273,945	27,776	1,435.0	3,927	276,147	460	299,132	24,433	290	....
1914...	11	1,263	283,860	27,090	1,500.0	3,048	252,666	700	286,600	25,933	196	14
1915...	......	......	289,000	34,319	1,670.0	2,750	285,000	700	293,000	25,729	371	3,145
1916...	......	......	....	....	....	......	....	....	....	......	**530**	**2,915**

(*a*) Reported by the Cuerpo de Ingenieros de Minas del Peru, in its *Boletin.* (*b*) Includes asphaltum and bituminous schist.

SPAIN

The following tables record the mineral and metal production of Spain as reported by official authorities:

MINERAL PRODUCTION OF SPAIN (*a*)
(In metric tons)

Year.	Aluminous Earths.	Antimony Ore.	Arsenic.	Asphaltum.	Asphalt, Rock.	Barytes.	Cement, Hydraulic.	Coal.	
								Anthracite.	Bituminous.
1902...	337	67	*Nil.*	6,034	6,301	642	201,856	109,298	2,614,010
1903...	381	42	1,088	4,675	6,277	507	245,294	108,959	2,587,652
1904...	925	245	400	3,463	3,761	453	286,737	163,275	2,903,771
1905...	221	77	1,140	5,805	5,725	290	296,605	159,517	2,912,466
1906...	386	180	1,114	6,229	7,794	330	299,294	113,747	3,095,043
1907...	1,209	205	1,500	8,643	8,219	314	329,926	164,498	3,531,337
1908...	60	124	2,004	9,231	12,373	334	343,001	188,463	3,696,653
1909...	35	(*b*)	506	6,582	5,284	422	472,909	198,302	3,662,573
1910(*f*)	400	15	444	8,473	7,795	476	484,161	211,958	3,600,056
1911...	461	100	331	3,495	6,500	635	486,085	209,227	3,454,394
1912(*h*).	....	500	....	5,387	....	1,096	....	226,663	3,625,666
1913(*i*).	....	....	....	5,582	....	3,049	....	232,517	3,783,214
1914...	....	....	....	....	....	....	....	....	....
1915...	....	300	....	4,521	....	4,218	....	222,621	4,135,919

Year.	Coal (*Continued*).		Coke.	Copper Ore.		Copper.			Fluorspar.
	Lignitic.	Briquets.		Argentiferous.	Pyritic.	Fine.	Matte.	Precipitate.	
1902...	84,242	331,957	404,503	878	2,617,776	(*b*)	.....	36,045	93
1903...	104,232	339,120	433,780	3,056	2,796,733	(*b*)	.....	27,448	4,000
1904...	100,773	307,630	432,726	(*b*)	2,624,512	(*b*)	8,117	29,494	(*b*)
1905...	168,994	290,830	448,073	(*b*)	2,621,054	(*b*)	8,243	17,988	(*b*)
1906...	189,048	311,328	435,808	(*b*)	2,888,778	(*b*)	9,068	19,200	70
1907...	191,001	355,718	476,360	(*b*)	3,182,645	(*b*)	9,886	20,887	270
1908...	223,160	296,216	477,059	(*b*)	2,985,779	(*b*)	205	19,599	253
1909...	265,019	(*b*)	500,909	(*b*)	2,955,254	(*b*)	2,077	16,641	246
1910(*f*)	245,518	474,891	521,078	(*b*)	3,231,418	85	2,684	14,056	180
1911...	252,051	478,143	516,342	(*b*)	3,284,184	(*g*)76	1,910	12,353	499
1912(*h*).	283,480	465,106	489,558	....	3,366,165	......	1,861	....	265
1913 *i*).	276,791	486,228	595,677	....	2,265,642	......	3,049	....	351
1914...	....	....	....	....	....	......	......	....	......
1915...	328,213	....	....	23,068	1,464,350	......	2,001	....	370

Year.	Iron Ore.		Iron and Steel.			Kaolin (China Clay).	Lead (Argentiferous).	
	Argentiferous.	Non-argentiferous.	Pig.	Wrought Iron.	Iron and Steel, Worked.		Ore.	Metal.
1902...	24,361	7,904,555	330,747	....	163,564	3,412	227,645	74,370
1903...	90,996	8,304,153	380,284	....	199,642	2,578	179,858	56,687
1904...	122,109	7,964,748	283,819	50,858	186,705	1,700	177,104	57,956
1905...	152,027	9,007,245	305,462	11,366	223,545	720	160,381	56,361
1906...	126,445	9,448,533	315,309	6,035	274,280	610	158,425	53,856
1907...	(*b*)	9,896,178	355,240	14,767	310,125	640	165,289	51,430
1908...	(*b*)	9,271,592	403,554	21,807	262,843	1,370	165,382	53,741
1909...	3,813	8,786,021	428,622	24,187	218,410	570	161,496	43,552
1910(*f*)	46,161	8,666,795	373,322	59,133	201,798	1,496	150,592	38,548
1911...	....	8,773,691	408,667	11,166	264,930	4,469	156,569	40,379
1912(*h*).	1,588	9,133,007	366,136	....	....	4,920	93,850	49,212
1913(*i*).	....	9,861,668	350,433	....	....	5,263	23,600	15,704
1914...	....	....	....	....	....	....	....	....
1915...	....	5,617,839	....	....	....	4,700	2,935	....

Year.	Lead (Non-argentiferous).		Manganese Ore.	Mineral Paints (Ocher).	Phosphate Rock.	Pyrites (Iron).	Pyrites (Arsenical).	Quicksilver.	
	Ore.	Metal.						Ore.	Metal.
1902 ...	100,403	103,190	46,069	(*b*)	1,150	145,173	5,648	26,037	1,425
1903 ...	108,660	118,422	26,194	(*b*)	1,124	155,739	7,996	30,370	968
1904 ...	93,230	127,906	18,732	(*b*)	3,305	161,841	3,510	27,185	1,130
1905 ...	105,113	129,332	26,020	(*b*)	1,370	179,079	4,790	26,485	853
1906 ...	105,095	131,614	62,822	164	1,300	189,243	2,434	28,965	1,568
1907 ...	103,632	135,066	41,504	114	3,547	225,830	3,423	28,789	1,212
1908 ...	126,667	134,321	16,745	400	4,483	263,451	5,533	42,210	1,068
1909(*f*).	137,050	136,441	7,827	418	1,387	258,931	3,235	37,398	1,393
1910...	216,738	151,975	8,607	759	2,840	294,184	1,461	22,714	1,114
1911...	165,843	149,540	5,607	622	3,520	344,879	1,056	19,940	1,494
1912(*h*).	190,162	183,400	17,400	....	3,292	421,070	....	21,898	1,256
1913(*i*).	279,078	173,125	21,594	....	3,548	926,913	....	19,960	1,246
1914 ...	....	....	8,965	....	....	....	....	....	....
1915 ...	285,266	....	14,328	....	....	730,568	....	20,717	1,000

Year.	Salt.	Silver.		Soapstone.	Sulphur.		Tin Ore, Dressed.	Topaz. *Kg.*	Tungsten Ore.	Zinc.		
		Ore.	Metal. *Kg.*		Crude Rock.	Refined.				Ore.	Spelter.	Sheets.
1902..	426,434	175	96,975	542	15,442	450	12,762	*Nil.*	11	127,618	5,569	(*b*)
1903..	427,394	231	112,978	3,725	38,573	1,608	330	90	*Nil.*	154,126	5,134	(*b*)
1904..	543,658	303	117,418	5,165	40,389	605	229	....	60	156,329	5,887	2,913
1905..	493,451	540	123,607	4,364	38,153	610	209	....	375	160,561	6,184	2,936
1906..	541,978	470	126,424	3,609	28,965	700	86	171	430	170,384	6,209	2,639
1907..	605,895	702	127,435	13,875	27,054	3,612	315	266	386	191,853	6,144	2,485
1908..	822,677	441	129,881	4,730	13,872	2,988	838	(*b*)	226	156,233	6,357	2,693
1909(*f*	800,703	388	143,403	5,583	21,750	3,429	(*e*) 1,555	(*b*)	129	163,522	9,625	(*b*)
1910..	678,057	217	129,157	4,665	30,113	3,834	35	149	153	156,113	8,557	2,722
1911..	654,767	858	110,082	5,647	40,662	6,580	34	......	96	162,140	2,904	3,429
1912(*h*	23,292	668	143,400	....	42,344	4,592	5,079	......	169	175,311	8,451	......
1913(*i*	26,238	405	266,606	....	62,653	7,499	6,626	......	235	174,831	7,935	......
1914..	....	....	....	....	....	......	....	......	......	....	....	......
1915..	305,035	210	....	963	28,937	......	102	......	511	81,922	....	......

(*a*) Figures are from *Estadistica Minera de España*. (*b*) Not reported. (*e*) Undressed tin ore. (*f*) *Revista Minera*, June 24, 1911. (*g*) Blister copper 18,295 tons, copper sulphate 15,893 tons (*h*) *Revista Minera*, Apr. 24, 1914. (*i*) *Revista Minera*, Feb. 24, 1915.

SWEDEN

The official statistics of mineral production, imports and exports, are summarized in the following tables:

MINERAL PRODUCTION OF SWEDEN (*a*)
(In metric tons)

Year.	Alum.	Coal.	Copper.			Feldspar.	Graphite.	Gold. *Kg.*
			Ore.	Ingot.	Sulphate.			
1903.....	140	320,390	36,687	776	1,171	19,392	25	50.6
1904.....	125	320,984	36,834	533	1,248	18,021	55	60.9
1905.....	139	322,384	39,255	1,385	1,029	19,224	40	55.0
1906.....	167	296,980	19,655	1,209	562	21,014	37	20.3
1907.....	131	305,338	21,957	1,577	782	20,244	33	28.1
1908.....	138	305,206	21,371	2,808	731	17,494	66	20.3
1909.....	132	246,808	9,562	2,375	628	15,772	26	14.1
1910.....	182	302,786	3,638	3,111	20	21,591	49	2.0
1911.....	159	311,809	1,623	3,221	320	36,235	65	11.0
1912.....	145	360,291	3,059	3,957	870	34,305	79	30.5
1913.....	144	363,965	5,458	6,891	428	37,878	88	25.0
1914.....	....	366,639	8,839	4,692	158	20,818	56	84.0
1915.....	....	412,261	10,549	4,561	....	12,105	87	37.0

Year	Iron and Steel.					Steel.		
	Ore.	Pig.	Blooms.	Bars, Rods, Sheets, etc.	Iron Sulphate.	Bessemer.	Basic.	Crucible.
1903....	3,677,520	506,825	192,342	325,200	62	84,229	232,878	1,105
1904....	4,083,945	528,525	189,246	324,676	148	78,577	252,832	1,162
1905....	4,364,833	539,437	182,640	356,898	144	78,204	288,675	1,319
1906....	4,501,656	604,789	178,298	381,118	170	84,633	311,435	1,457
1907....	4,478,917	615,778	174,405	403,994	159	77,036	341,893	1,287
1908....	4,712,494	567,821	152,256	363,408	277	81,054	355,394	1,169
1909....	3,885,046	444,764	120,669	292,478	182	63,351	248,757	927
1910....	5,549,987	603,929	151,713	408,191	236	97,503	372,451	2,215
1911....	6,150,718	634,392	146,722	408,159	156	93,853	372 705	4,309
1912....	6,699,226	699,816	....	....	....	107,254	307,637	....
1913....	7,475,571	730,257	....	....	320	**115,700**	467,100	....
1914....	6,586,630	639,718	241,652	500,827	651	93,210	409,528	2,826
1915....	6,883,308	767,600	....	....	....	....	....	....

Year.	Lead.	Mangan-ese Ore.	Pyrite.	Silver-Lead Ore.	Silver. *Kg.*	Nickel Ore	Zinc Ore.
1903.......	678	2,244	7,793	9,792	1,005	....	48,783
1904.......	589	2,297	15,957	8,187	651	....	62,927
1905.......	576	1,992	20,762	8,397	606	....	57,634
1906.......	753	2,680	21.827	1,938	938	....	56,885
1907.......	813	4,334	27,113	1,987	929	....	52,552
1908.......	277	4,616	29,569	2,058	630	....	50,884
1909.......	166	5,212	16,104	1,721	512	....	40,077
1910.......	355	5,752	25,445	2,700	30	....	43,760
1911.......	1,134	5,377	30,096	2,999	1,289	....	49,453
1912.......	1,073	5,101	31,835	2.877	962	....	51,242
1913.......	1,235	4,001	34,319	3,222	1,037	....	50,752
1914.......	1,396	3,643	33,313	3,110	1,074	156	42,279
1915.......	1,918	7,607	76,324	2,671	754	1,642	55,937

(*a*) From *Bidrag till Sveriges Officiela Statistik Bergshandteringen.*

MINERAL IMPORTS OF SWEDEN (*a*)
(In metric tons or dollars; 1 krone =27 cents)

Year.	Asbestos. (*c*)	Asphalt.	Barytes.	Borax.	Boric Acid.	Bromine and Bromides. *Kg.*	Cement.	Chalk, White, Unground. *Hectoliters.*	Coal.
1900....	763	5,676	411	194	66	6,084	1,941	12,059	3,033,885
1901....	178	4,524	295	253	68	6,602	2,868	13,569	2,793,309
1902....	213	5,779	....	242	71	7,278	9,822	11,583	2,911,286
1903....	217	5,957	....	240	71	7,419	11,145	41,868	3,192,990
1904....	356	6,243	....	299	77	10,128	10,526	10,115	3,367,826
1905....	140	4,760	264	294	82	18,788	10,999	13,305	3,297,485
1906....	287	7,134	559	321	79	9,908	13,136	10,777	3,718,884
1907....	672	8,213	610	490	85	6,784	17,801	(*g*) 860	4,146,785
1908....	505	6,368	514	347	71	11,499	6,158	(*g*) 419	4,427,507
1909....	383	7,922	529	365	76	10,280	12,944	(*g*) 512	4,084,055
1910....	671	7,406	625	379	92	10,913	15,438	(*g*) 473	4,180,250
1911....	1,011	6,803	607	381	76	16,819	24,830	(*g*) 605	3,964,870
1912....	635	7,645	644	434	199	9,319	17,438	(*g*) 422	4,293,719
1913....	1,094	6,809	610	470	120	11,211	12,120	(*g*) 2,337	4,878,854
1914....	415	7,348	....	462	127	21,064	14,769	....	4,626,932

Year.	Copper, also Alloys of Copper.	Emery.	Graphite.	Gypsum.	Iron, Crude.	Lead.	Litharge.	Phosphorus. *Kg.*	Platinum. *Kg.*
1900....	4,745	136	213	6,794	82,957	2,067	148	67,557	59
1901....	5,153	169	180	6,589	66,131	1,991	165	70,672	172
1902....	6,890	147	(*b*)	6,754	43,828	2,509	172	68,441	130
1903....	6,109	132	(*b*)	8,795	49,411	2,644	237	112,659	116
1904....	7,367	221	(*b*)	8,868	90,102	2,849	213	47,421	84
1905....	6,481	271	(*b*)	11,270	87,843	2,823	205	69,526	105
1906....	8,899	284	(*b*)	13,496	108,193	3,457	255	79,048	133
1907....	(*c*) 14,213	336	375	15,037	115,186	3,384	210	77,936	109
1908....	(*c*) 12,392	308	540	11,644	109,841	3,964	248	107,301	117
1909....	(*c*) 11,000	428	443	14,212	99,519	3,222	217	88,241	72
1910....	(*c*) 13,297	438	398	15,816	117,180	3,453	267	99,145	77
1911....	(*c*) 14,014	459	398	14,505	114,859	2,901	270	77,837	103
1912....	7,470	490	513	10,467	140,145	1,204	316	88,411	12
1913....	9,189	667	576	13,284	102,744	2,676	327	92,487	23
1914....	12,048	....	336	13,210	....	2,427	474	140,040	8.4

Year.	Potassium.				Quicksilver. *Kg.*	Salt.		Silver.	
	Chloride.	Cyanide. *Kg.*	Hydrate.	Carbonate.		Crude.	Refined.	Bullion and Mfrs. *Kg.*	Specie.
1900......	364	2,221	1,915	1,257	3,629	70,302	3,098	11,559	$ 62,315
1901.....	260	2,658	1,435	1,266	5,958	79,038	3,072	7,476	78,416
1902....	222	2,950	1,720	1,238	4,866	82,439	3,037	4,853	74,826
1903.....	245	3,294	2,034	1,150	5,043	88,139	3,419	11,259	90,366
1904.....	214	3,237	2,234	1,184	5,768	84,237	4,615	19,034	86,891
1905.....	1,296	3,437	2,251	1,133	4,609	87,677	3,889	11,067	82,620
1906.....	1,986	4,106	2,486	1,082	5,535	88,341	3,700	15,253	93,990
1907.....	1,840	4,150	2,484	1,269	8,930	(*h*) 835,190	18,821	26,334	52,074
1908.....	2,190	3,563	2,835	1,209	7,299	(*h*) 903,633	24,394	20,149	93,669
1909.....	1,809	3,808	2,627	1,312	6,077	(*h*) 766,195	24,143	17,315	154,265
1910....	2,335	4,272	2,767	1,346	7,079	(*h*) 766,512	22,425	21,162	75,604
1911.....	1,288	4,993	3,737	1,268	4,164	(*h*) 736,935	26,026	15,175	134,407
1912.....	228	7,545	(*i*) 3,262	1,380	5,110	1,050	22,009	21,220	164,781
1913.....	2,081	7,607	(*i*) 5,234	1,417	5,142	911	24,927	20,550	....
1914.....	2,640	4,634	(*i*) 5,127	....	5,823	(*h*) 969,926	25,119	26,019	....

Year.	Sodium.				Sulphur.	Sulphuric Acid.	Tin.		Zinc.
	Carbonate.	Hydrate.	Nitrate. (*d*)	Sulphate. (*e*)			Salts. *Kg.*	Block.	
1901....	13,669	800	17,614	15,494	20,715	1,950	2,334	541	2,900
1902....	....	1,623	15,553	18,924	23,002	1,887	1,652	644	3,255
1903....	....	1,426	20,616	16,120	24,577	2,620	1,467	655	3,312
1904....	11,898	2,112	19,776	17,596	18,248	2,001	1,460	719	3,705
1905....	13,592	1,489	23,183	17,115	18,631	3,424	1,722	597	3,780
1906....	14,974	1,478	27,174	19,948	22,745	2,535	1,102	819	4,484
1907....	14,970	1,628	26,181	21,486	25,456	2,628	6,117	891	5,407
1908....	14,149	1,256	27,631	18,717	30,806	3,073	2,817	808	4,626
1909....	13,490	1,119	28,849	20,226	26,836	1,955	1,357	794	5,294
1910....	15,594	1,260	32,315	22,429	38,530	2,707	1,161	764	5,843
1911....	15,777	2,501	31,324	27,482	34,622	861	915	866	5,951
1912....	18,255	....	35,107	26,540	38,471	593	73,045	1,032	4,617
1913....	18,473	....	33,891	31,740	39,715	1,114	56,982	1,083	3,699
1914....	18,698	....	41,657	32,401	36,054	455	55,931	1,482	5,777

MINERAL EXPORTS OF SWEDEN (*a*)
(In metric tons or dollars; 1 krone = 27 cents)

Year.	Alum.	Ammonium Sulphate.	Antimony, Crude. *Kg.*	Asbestos. *Kg.*	Cement.	Coal (Anthracite).	Copper.		Graphite
							Ore.	Copper and Alloys.	
1899 ...	26	2	2,600	2,812	31,101	762	315	1,230	17
1900 ...	24	2	4,600	2,436	42,564	1,108	448	2,012	18
1901 ...	56	156	1,800	2,179	17,794	716	602	1,243	19
1902 ...	20	174	4,090	1,864	19,499	866	845	1,516	5
1903 ...	22	*Nil.*	3,473	15,357	21,319	509	1,555	1,858	9
1904 ...	9	219	3,810	16,339	27,509	605	749	1,396	(*b*)
1905 ...	12	445	3,147	2,386	38,504	425	2,137	2,654	(*b*)
1906 ...	11	30	4,584	1,510	45,960	1,352	1,841	2,662	(*b*)
1907 ...	7	*Nil.*	4,485	2,167	18,053	2,925	882	2,762	8
1908 ...	9	202	4,188	1,612	34,164	1,293	1,114	3,299	18
1909 ...	5	331	6,536	1,093	33,197	771	723	3,264	7
1910 ...	11	704	4,555	1,242	73,351	776	878	2,580	7
1911 ...	2	253	7,320	760	108,653	1,045	1,114	2,500	12
1912 ...	15	42	9,151	564	127,142	684	1,577	4,273	9
1913 ...	6	254	6,803	1,066	137,074	419	1,709	3,495	48
1914 ...	18	90	....	1,743	39,347	326	1,352	4,045	133

Year.	Gypsum and Mfrs.	Iron and Steel.		Lead and Mfrs.	Peat.	Phosphorus. *Kg.*	Potassium Chloride.
		Ore.	Unwrought.				
1899........	8	1,628,011	320,742	818	1,979	1,890	335
1900........	10	1,619,902	304,175	1,209	3,843	879	931
1901........	55	1,761,257	268,143	1,028	3,064	1,254	708
1902........	117	1,729,000	(*f*) 73,403	546	3,620	1,290	1,114
1903........	119	2,828,000	(*f*) 70,788	333	3,217	300	790
1904........	162	3,065,522	(*f*) 88,124	275	4,212	1,994	1,266
1905........	156	3,316,626	(*f*)120,987	512	5,157	34,388	1,499
1906........	6	3,661,218	(*f*)112,719	531	6,531	700	(*b*)
1907........	16	3,521,717	201,643	519	6,524	(*b*)	(*b*)
1908........	37	3,654,268	159,095	496	5,559	400	1,363
1909........	21	3,204,522	161,757	319	9,999	1,305	1,400
1910........	41	4,434,805	213,861	557	9,754	265	1,383
1911........	13	5,086,898	226,044	1,181	10.371	595	1,564
1912........	2	5,520,653	213,619	1,003	7,276	600	1,653
1913........	1	6,413,644	216,013	745	7,135	900	1,423
1914........	47	4,786,314	....	299	....	19,025	....

Year.	Salt, Refined. *Kg.*	Silver Bullion. *Kg.*	Soda (Carbonate).	Sulphur.	Tin.		Zinc.	
					Block and Scrap.	Mfrs. *Kg.*	Ore.	Crude and Mfrs.
1899....	110	367	227	68	8.8	1,033	45,635	157
1900....	407	296	238	20	21.5	1,521	40,879	157
1901....	1,556	179	237	12	20.4	8,110	41,248	101
1902....	1,945	110	621	147	25.5	1,603	43,813	63
1903....	*Nil.*	484	10	217	43.3	3,893	45,389	351
1904....	1,883	115	45	4	45.6	3,479	44,259	332
1905....	*Nil.*	10	403	4	33.9	654	51,765	295
1906....	8,652	77	463	12	51.0	353	45,380	410
1907....	4,452	160	39	1	67.9	2,518	41,236	529
1908....	14,300	136	114	7	53.9	274	38,543	908
1909....	6,422	437	27	5	42.5	276	38,865	1,200
1910....	1,326	814	31	6	51.1	356	40,405	1,278
1911....	3,450	1,090	40	7	66.0	152	41,854	2,158
1912....	1,668	2,021	3	75	110.0	698	41,985	3,136
1913....	6,916	4,300	2	239	87.0	2,640	46,696	6,533
1914....	....	3,465	30	80	517.4	2,985	41,499	6,426

(*a*) From *Bidrag till Sveriges Officiella Statistik* and *Sveriges Utförsel och Införsel.* (*b*) Not reported. (*c*) Includes crude and manufactures. (*d*) Includes a small quantity of potassium nitrate. (*e*) Includes sodium bisulphate. (*f*) Includes only crude or ballast iron. (*g*) Metric tons. (*h*) Hectoliters (*i*) Includes sodium hydroxide.

UNITED KINGDOM

The statistics of the mineral production, imports and exports, according to official reports, are given in the subjoined tables. Figures given in full-faced type are either provisional figures or estimates.

MINERAL AND METALLURGICAL PRODUCTION OF THE UNITED KINGDOM (*a*)
(In metric tons)

Year.	Alum Shale.	Arsenious Acid.	Arsenical Pyrites.	Barium Minerals.	Bauxite.	Chalk.	Clay. (*e*)	Coal.
1904....	6,636	992	44	26,748	8,839	4,509,768	16,210,734	236,130,373
1905....	7,245	1,552	651	29,528	7,417	4,608,153	15,376,910	239,906,999
1906....	9,605	1,625	650	36,319	6,760	4,825,299	12,459,213	255,067,622
1907....	10,063	1,523	1,800	42,648	7,658	4,855,857	15,065,141	272,097,858
1908....	5,459	2,007	3,270	39,572	11,904	4,329,983	14,638,710	265,726,332
1909....	9,266	2,926	182	42,436	9,652	4,508,136	14,293,598	268,007,890
1910....	6,781	2,187	958	45,384	4,208	4,705,766	(*h*)14,316,469	268,677,182
1911....	10,685	2,178	1,189	44,826	6,103	5,965,423	14,057,090	276,255,764
1912....	11,446	2,228	1,806	43,453	5,882	4,962,408	13,022,433	264,749,661
1913....	8,887	1,716	36	48,792	6,153	4,939,095	14,090,818	292,047,544
1914....	6,179	2,007	(*b*)	49,718	8,421	4,362,689	13,343,100	270,070,414
1915....	8,038	2,537	428	63,483	11,914	3,285,963	9,014,657	257,282,699
1916....	....	2,574	....	70,559	10,495	....	....	257,255,635

Year.	Copper.		Fluorspar.	Gold.		Gravel and Sand.	Gypsum.	Bog Ore (Ireland). (*c*)
	Ore and Precipitate.	Fine.		Ore.	Bullion. *Kg.*			
1904......	5,552	501	18,450	23,574	610.7	2,275,426	237,749	4,616
1905......	7,267	727	40,079	16,237	169.0	2,277,486	259,596	3,256
1906......	7,882	(*b*)	42,521	17,662	(*b*)	2,404,857	228,627	5,512
1907......	6,867	677	50,257	13,186	59.4	2,438,798	239,285	6,391
1908......	5,528	588	35,257	7,237	28.5	2,228,245	231,980	4,364
1909......	3,777	442	43,165	5,627	37.6	2,199,583	242,832	2,719
1910......	4,245	456	62,607	6,252	75.5	2,235,160	259,661	2,603
1911......	3,314	398	56,117	2,796	13.2	2,311,694	281,125	2,743
1912......	1,942	296	29,154	173	49.7	2,227,975	247,724	3,397
1913......	2,108	428	54,557	4	4.9	2,449,305	242,341	3,899
1914......	2,561	347	34,360	55	3.2	2,540,520	269,637	2,381
1915......	835	238	33,656	5,169	39.1	2,388,106	251,209	2,018
1916......	952	....	35,103	1,360	....	....	191,841	....

Year.	Iron.		Lead.		Manganese Ore.	Mineral Paints.	Oil Shale.	Phosphate of Lime.
	Ore.	Pig.	Ore.	Pig.				
1904....	13,994,670	4,596,803	26,796	20,155	8,896	16,307	2,370,391	59
1905....	14,824,183	(*f*)9,746,221	28,091	20,977	14,582	16,468	2,536,784	*Nil.*
1906....	15,748,412	(*f*)9,999,211	30,710	22,693	23,126	14,437	2,586,851	*Nil.*
1907....	15,983,310	(*f*)9,850,953	33,053	24,853	16,356	14,927	2,732,968	33
1908....	15,272,273	4,925,250	29,718	21,336	6,409	15,643	2,938,456	9
1909....	15,220,408	(*f*)9,818,916	30,221	22,823	2,812	16,575	3,014,678	4
1910....	15,470,392	5,055,595	28,992	21,867	5,554	16,782	3,180,520	*Nil.*
1911....	15,768,511	5,101,089	24,186	18,279	5,067	14,819	3,166,838	....
1912....	8,552,343	4,525,830	25,729	19,473	4,237	14,179	3,235,942	....
1913....	16,263,950	5,224,607	24,656	18,462	5,480	15,387	3,333,048	....
1914....	15,115,375	4,865,858	26,422	19,684	3,494	11,247	3,321,291	....
1915....	14,464,196	4,640,885	21,078	15,767	4,716	9,134	3,046,910	....
1916....	....	....	17,359	....	....	4,688	....	....

Year.	Pyrite.	Salt.	Silica (Chert and Flint).	Silver. *Kg.*	Stone.			
					Igneous Rock.	Limestone. (*d*)	Sandstone.	Slate.
1903.......	9,794	1,917,274	74,355	5,440	5,512,605	12,419,120	5,496,312	540,143
1904.......	10,452	1,921,899	66,300	4,967	6,084,642	12,235,825	5,391,265	572,181
1905.......	12,381	1,920,149	71,808	5,212	6,052,210	12,701,808	5,729,799	523,892
1906.......	11,318	1,996,593	69,300	(*b*)	6,264,402	12,962,725	5,345,328	500,546
1907.......	10,358	2,016,409	54,523	4,780	5,765,262	12,709,288	5,092,246	450,651
1908.......	9,600	1,873,555	64,813	4,207	6,211,860	11,977,007	5,105,481	420,979
1909.......	8,964	1,851,999	53,063	4,421	6,384,144	12,000,790	4,673,839	408,639
1910.......	10,393	2,083,543	75,089	4,251	6,714,774	12,713,565	4,456,679	423,006
1911.......	10,276	2,116,115	72,726	3,684	6,629,417	12,378,725	4,109,828	431,948
1912.......	10,691	2,157,621	75,963	3,955	6,748,852	11,692,338	3,903,560	389,812
1913.......	11,611	2,285,221	76,105	4,439	7,216,801	12,953,008	4,043,591	376,935
1914.......	11,848	2,103,316	77,483	4,555	7,250,120	12,361,082	3,520,306	324,227
1915.......	10,711	2,037,895	104,351	3,000	6,183,390	11,294,875	2,561,442	229,676

Year.	Strontium Sulphate.	Tin.		Tungsten Ore.	Uranium Ore.	Zinc.	
		Ore, Dressed.	Block.			Ore.	Spelter.
1904...........	18,460	6,849	4,198	164	*Nil.*	28,097	10,427
1905...........	14,523	7,316	4,540	174	105	24,025	9,023
1906...........	14,338	6,376	(*b*)	267	11	23,189	(*b*)
1907...........	10,917	7,192	4,478	327	72	20,402	7,222
1908...........	16,733	8,137	5,133	237	72	15,469	5,926
1909...........	14,267	8,422	5,282	382	6	10,061	5,828
1910...........	4,838	7,693	4,874	275	76	11,418	4,235
1911...........	5,963	7,870	4,950	270	68	17,935	6,196
1912...........	19,693	8,302	5,342	192	43	17,988	60,163
1913...........	18,732	8,494	5,376	185	96	18,073	5,920
1914...........	13,376	8,220	5,144	208	350	15,676	5,295
1915...........	650	8,275	5,048	334	83	12,254	4,162
1916...........	....	6,260	....	394	52	8,612	....

(*a*) From *Mineral Statistics of the United Kingdom.* (*b*) Not reported. (*c*) Bog ore, which is mined in Ireland, is an ore of iron, used principally for purifying gas. (*d*) Does not include chalk. (*e*) Includes China clay, potters' clay, and fuller's earth. (*f*) Includes production from imported ore. (*h*) Includes shale.

MINERAL IMPORTS OF THE UNITED KINGDOM (*a*)

(In metric tons or dollars; £1 = $5)

Year.	Alkali.	Asphaltum.	Borax.	Coal, Coke, and Pat. Fuel.	Copper.			Iron and Steel.		
					Ore.	Regulus and Precipitate.	Wrought, Unwrought and Old.	Iron Ore.	Pig Iron.	Scrap.
1905...	(*c*)16,593	(*b*)	11,552	49,277	94,198	70,235	71,294	7,172,171	128,183	23,569
1906...	(*c*)14,070	(*b*)	16,955	49,269	97,789	76,073	75,487	7,634,839	90,674	36,559
1907...	(*c*)15,579	(*b*)	17,551	19,136	105,409	73,101	89,312	7,764,589	104,950	27,404
1908...	(*c*)13,732	(*b*)	(*n*)19,424	3,904	111,897	71,120	124,226	6,154,733	69,930	24,653
1909(*i*)	(*c*)10,857	(*b*)	(*n*)16,349	6,419	(*l*)90,579	(*l*)66,337	(*l*)133,758	(*l*)6,429,996	(*l*)111,30	(*l*)33,475
1910...	(*c*) 8,996	(*o*)14,415	16,277	36,615	99,755	70,081	89,279	7,133,483	173,680	70,176
1911...	(*c*) 9,463	(*o*)20,866	20,621	30,672	87,986	65,914	101,059	6,448,462	178,167	51,002
1912...	8,812	(*b*)	21,091	194,866	99,802	52,393	96,499	6,708,443	223,586	64,195
1913...	9,140	(*b*)	23,837	24,429	95,837	39,762	108,728	7,566,276	220,320	124,854
1914...	10,583	....	20,493	45,315	72,766	43,252	152,974	5,799,918	227,099	112,405
1915...	8,757	....	21,672	3,843	38,766	39,011	183,393	6,306,547	202,500	115,150
1916...	7,789	....	18,850	3,257	35,047	44,545	113,206	7,017,122	162,111	99,432

Year.	Iron and Steel (*Continued*).								Lead.	
	Puddled and Wrought	Sheets and Plates.	Rails.	Strips, Wire, and Wire Rods.	Nails, Screws, Rivets, Bolts.	Steel Ingots, Blooms, Billets, etc.	Steel Bars, Shapes, Beams, Pillars.	Mnfrs. Unenumerated. (*h*)	Ore.	Pig and Sheet.
1904..	109,289	69,552	40,438	38,214	50,649	531,069	219,510	$8,630,380	8,748	250,452
1905..	110,576	69,831	34,439	60,318	55,331	613,612	148,995	8,783,895	(*i*)27,649	233,214
1906..	111,062	83,747	11,900	61,288	57,071	493,805	149,363	7,824,405	(*i*)30,795	211,577
1907..	83,145	57,280	19,33	56,110	51,863	332,442	90,327	3,731,275	(*i*)13,609	207,970
1908(*i*)	85,270	56,652	31,393	109,313	54,251	437,238	231,859	3,034,895	23,861	241,320
1909..	(*l*) 95,553	(*l*) 68,067	(*l*) 22,430	(*l*) 132,543	(*l*) 59,197	(*l*) 392,008	(*l*) 264,909	2,819,365	(*b*)	(*l*)210,982
1910..	(*l*) 98,859	88,245	16,074	163,681	58,977	361,401	349,662	3,239,715	(*b*)	222,450
1911..	119,583	115,349	36,588	173,764	62,314	512,841	500,643	(*p*)3,654,825	(*b*)	217,134
1912 .	167,774	103,224	24,640	205,749	73,745	607,470	509,002	4,270,000	(*b*)	208,671
1913..	204,218	172,301	38,701	225,690	66,086	568,512	597,591	10,098,040	(*b*)	207,559
1914..	132,194	121,433	24,033	179,772	62,317	325,245	459,771	8,852,884	....	227,931
1915..	46,775	31.016	15,956	199,558	65,410	453,617	108,939	8,678,975	....	260,751
1916..	44,922	40,861	5,198	140,257	80,469	166,746	96,306	6,833,717	....	160,529

Year.	Manganese Ore.	Mica, Sheet.	Mica and Talc.	Paraffin.	Petroleum. *Liters.*	Phosphate Rock.	Platinum, Wrought and Unwrought. *Kg.*	Potassium Nitrate.	Pyrites of Iron and Copper.
1904.......	208,458	(*b*)	(*b*)	42,882	1,373,488,176	425,978	(*b*)	12,277	754,722
1905.......	289,827	(*b*)	(*b*)	41,247	1,364,301,583	427,762	(*b*)	8,260	709,926
1906.......	314,016	(*b*)	(*b*)	44,673	1,130,667,737	450,058	(*b*)	10,125	771,473
1907.......	513,750	(*b*)	(*b*)	46,542	1,382,595,355	512,601	(*b*)	10,719	781,486
1908 (*i*)....	349,694	(*b*)	(*b*)	(*n*) 46,504	(*n*) 1,300,726,576	537,628	(*b*)	(*n*) 11,913	771,091
1909.......	335,813	(*b*)	(*b*)	(*n*) 53,289	(*n*) 1,355,562,599	459,058	(*b*)	(*n*) 10,704	(*l*) 803,725
1910.......	489,948	(*b*)	(*b*)	(*n*) 54,073	(*n*) 1,308,396,240	462,905	(*b*)	11,558	825,284
1911.......	364,676	(*b*)	(*b*)	51,456	1,661,100,144	501,332	(*b*)	11,376	863,583
1912.......	393,798	(*b*)	(*b*)	74,836	1,879,486,588	528,620	(*b*)	11,034	921,717
1913.......	611,227	(*b*)	(*b*)	57,974	(*g*) 488,106,963	548,000	(*b*)	12,092	794,740
1914.......	487,426	......	......	53,576	(*g*) 646,894,523	564,865	....	10,666	816,449
1915.......	383,613	......	......	93,677	(*g*) 588,469,699	380,883	....	14,060	918,468
1916.......	446,585	......	......	75,217	(*g*) 451,931,774	338,738	....	22,317	966,520

Year.	Quicksilver.	Silver Ore. (*d*)	Sodium Nitrate.	Sulphur.	Tin.		Zinc.		
					Ore.	Block, Ingot, Bars or Slabs.	Ore.	Spelter.	Mnfrs.
1904........	1,130	$8,271,480	122,454	17,629	15,734	39,932	54,438	90,088	22,788
1905........	1,158	10,426,570	106,107	18,163	(*b*)	40,391	23,909	92,261	20,013
1906........	1,320	10,532,020	110,222	22,704	21,003	44,306	(*i*) 22,824	95,203	19,164
1907........	1,341	11,224,650	115,716	15,730	21,205	44,505	(*i*) 66,076	90,756	20,663
1908(*i*)......	1,483	10,743,400	(*n*) 148,056	(*n*) 19,580	25,414	48,496	61,661	91,548	38,717
1909........	(*m*) 1,469	10,409,800	(*n*) 91,650	21,211	(*m*) 24,471	(*l*) 42,393	(*b*)	104,217	19,280
1910........	1,517	9,311,665	128,528	20,496	26,490	47,028	(*b*)	123,061	18,460
1911........	1,584	8,420,954	130,549	21,269	29,300	46,643	(*b*)	117,077	19,417
1912........	1,607	7,523,692	125,664	22,109	29,112	43,850	(*b*)	139,461	20,673
1913........	1,543	5,718,552	143,275	18,518	35,169	46,443	(*b*)	147,421	19,081
1914........	1,283	4,324,576	174,775	22,162	32,938	41,644	....	117,660	12,690
1915........	1,381	3,446,485	134,360	36,247	45,494	39,544	....	75,762	8,170
1916........	1,159	3,429,646	21,232	37,281	34,458	34,188	....	54,183	3,729

(*a*) From *Accounts Relating to Trade and Navigation of the United Kingdom.* (*b*) Not reported. (*c*) Classified as soda compounds since 1901. (*d*) Includes the value of silver in argentiferous ore and metal. (*f*) Not separately enumerated. (*g*) Gallons. (*h*) Prior to 1900, many manufactures were not reported separately. (*i*) From *Mines and Quarries.* (*l*) From *Iron and Coal Trades Review.* (*m*) *Min. Journ.* (*n*) *Oil, Paint and Drug Reporter.* (*o*) From Trinidad. (*p*) There are besides, not here given, pipes, castings and forgings amounting to 51,000 tons.

MINERAL EXPORTS OF THE UNITED KINGDOM—DOMESTIC PRODUCTS (*a*)
(In metric tons or dollars; £1 = $5)

Year.	Bleaching Materials.	Cement.	Coal.	Coke.	Patent Fuel.	Supplied to Steamers.	Coal Products. (*c*)
1904	35,289	390,736	46,995,636	779,060	1,257,589	17,465,954	6,879,400
1905	42,526	463,863	48,236,334	786,498	1,126,190	17,674,484	6,742,455
1906	45,510	668,461	56,489,367	828,266	1,399,244	18,887,656	7,226,790
1907	48,856	777,741	64,621,743	997,170	1,504,661	18,917,660	7,726,685
1908	39,120	607,950	63,551,057	1,212,184	1,463,557	19,786,734	(*n*) 7,711,360
1909(*k*)	(*n*) 46,321	607,825	64,089,132	(*l*) 1,180,218	(*l*) 1,479,142	20,029,427	(*n*) 7,276,050
1910	(*n*) 51,188	747,627	(*l*) 63,081,948	979,526	1,494,397	(*l*) 19,839,123	(*n*) 8,398,405
1911	46,416	727,092	65,636,084	1,076,887	1,638,625	19,573,379	£2,517,355
1912	41,989	656,460	65,479,346	1,042,489	1,590,557	18,584,946	£2,981,159
1913	36,928	761,232	74,623,453	1,254,502	2,087,407	21,382,032	£2,279,790
1914	30,458	608,344	60,023,878	1,202,562	1,634,553	18,844,505	£2,283,062
1915	25,086	432,243	44,260,350	1,027,140	1,245,489	13,858,147	£2,554,008
1916	8,794	416,602	38,969,013	1,505,350	1,346,023	13,197,282	£3,212,046

Year.	Copper.				Iron.				
	Ingot.	Mixed or Yellow Metal.	Mfrs.	Sulphate.	Ore.	Pig.	Scrap.	Cast Iron and Mfrs.	Wrought Iron, Shapes and Mfrs.
1904	14,791	16,704	18,467	71,367	6,706	823,909	166,010	49,004	173,233
1905	21,232	9,959	22,128	55,219	14,664	997,601	151,619	49,193	186,340
1906	19,778	7,149	16,195	43,670	13,415	1,670,753	180,547	54,876	203,521
1907	25,652	7,994	16,676	46,049	15,538	1,978,350	162,295	43,218	215,159
1908(*k*)	14,869	15,546	19,796	(*m*) 72,429	4,478	1,317,330	135,115	48,336	174,539
1909	12,465	(*m*) 11,381	17,248	(*m*) 45,547	(*l*) 5,185	(*l*) 1,026,517	(*l*) 165,183	(*l*) 44,406	(*l*) 171,697
1910	11,898	(*m*) 15,970	12,551	43,391	(*l*) 7,464	(*l*) 1,062,444	(*l*) 150,507	(*l*) 57,148	(*q*) 143,702
1911	10,970	15,101	24,669	81,112	(*l*) 6,352	1,222,622	147,759	(*l*) 70,618	140,318
1912	12,993	11,108	19,327	85,497	6,241	1,284,220	127,610	68,676	144,747
1913	15,165	14,711	22,317	76,950	5,278	1,142,917	117,645	82,816	139,593
1914	7,390	13,420	18,367	69,015	13,742	793,703	90,037	73,339	151,062
1915	6,764	3,923	14,076	66,297	1,697	621,810	52,031	47,647	121,826
1916	9,339	1,654	8,114	39,437	1,263	932,166	62,596	36,895	140,158

Year.	Iron (*Continued*).								
	Rails.	Wire and Mfrs. of.	Plates and Sheets.	Galvanized Sheets.	Black Plates for Tinning.	Tinned Plates.	Steel Ingots, Billets, Blooms, etc.	Steel Shapes, Beams, and Pillars.	Total Iron and Steel, and Mfrs. of.
1904	533,895	61,894	154,774	391,608	63,467	365,262	4,324	176,232	3,315,049
1905	555,390	82,519	207,866	413,533	69,937	360,630	8,735	219,491	3,781,058
1906	470,652	96,641	279,459	450,221	66,749	381,421	11,924	311,231	4,763,868
1907	595,272	103.100	305,399	476,838	72,675	411,814	13,705	344,135	5,249,028
1908(*k*)	589,525	95,801	210,526	396,366	62,079	409,335	2,452	278,792	4,162,065
1909	(*l*) 589,499	(*l*) 107,406	(*l*) 169,918	(*l*) 502,791	(*l*) 61,025	(*l*) 446,781	(*l*) 3,217	(*l*) 309,555	4,278,172
1910	490,068	(*l*) 124,703	(*l*) 197,858	(*l*) 606,530	(*l*) 56,691	(*l*) 490,733	(*l*) 3,340	(*q*) 230,850	4,661,647
1911	381,320	(*l*) 129,252	(*l*) 203,850	627,215	(*l*) 68,137	492,104	(*f*) 4,376	231,793	4,588,385
1912	418,742	121,215	218,585	669,252	66,775	488,629	4,241	245,033	4,891,270
1913	517,251	118,814	204,452	774,948	72,977	503,170	4,942	255,580	5,017,456
1914	451,030	100,938	145,017	576,044	58,192	442,755	5,784	328,061	3,946,688
1915	257,552	64,407	250,400	291,187	54,383	374,742	16,106	555,115	3,248,454
1916	55,263	53,281	340,741	119,097	139,138	326,890	84,186	642,469	3,349,294

Year.	Lead, Pig and Mfrs.	Salt.	Sodium.				Tin, Block	Zinc.		
			Soda Ash.	Carbonate and Bicarbonate.	Hydrate.	Sulphate.		Ore.	Spelter.	Mfrs.
1904 ..	35,600	632,605	61,327	25,252	61,985	40,324	5,953	14,606	7,930	(*i*)
1905 ..	42,265	588,389	67,678	28,425	68,675	33,681	7,741	(*b*)	7,451	(*i*)
1906 ..	45,612	629,658	86,232	26,970	72,218	44,448	8,631	(*b*)	7,962	(*i*)
1907 ..	44,068	592,989	91,120	29,539	70,432	45,898	8,808	11,511	6,666	(*i*)
1908(*k*)	50,221	532,101	(*n*) 83,713	(*n*) 20,805	(*n*) 73,769	(*n*) 22,974	9,486	3,833	8,537	(*i*)
1909 ..	(*m*) 46,399	523,690	(*n*) 97,480	(*n*) 23,378	(*n*) 80,439	(*n*) 35,587	11,373	(*b*)	(*m*) 8,684	(*i*)
1910 ..	47,588	571,845	110,188	23,295	84,291	58,960	12,576	(*b*)	9,247	(*i*)
1911 ..	44,733	614,572	125,945	26,353	82,356	59,382	11,736	(*b*)	9,736	(*i*)
1912 ..	47,782	557,291	144,073	29,403	79,527	50,759	12,152	(*b*)	10,881	......
1913 ..	49,261	542,157	159,714	39,175	76,152	67,504	11,687	....	11,313	......
1914 ..	36,486	504,848	181,754	37,724	75,618	40,366	13,599	....	7,580	......
1915 ..	40,835	508,022	221,850	43,517	56,781	31,931	14,389	......	2,428	......
1916 ..	28,883	396,518	159,770	45,268	29,670	24,760	18,315	......	3,621	......

(*a*) From *Accounts Relating to Trade and Navigation of the United Kingdom.* (*b*) Not reported. (*c*) Including naphtha, paraffin, paraffin oil and petroleum. (*d*) Previous reports not available. (*e*) Includes puddled iron. (*f*) Includes railroad material of all kinds. (*g*) Includes all soda compounds; not separate; enumerated previous to 1901. (*h*) Included under soda ash. (*i*) Included under spelter. (*k*) From *Mines and Quarries.* (*l*) From *Iron and Coal Trades Review.* (*m*) *Mining Journal.* (*n*) From *Oil Paint and Drug Reporter.* (*q*) Bars only.

UNITED STATES

Of the following tables, the first records the imports of foreign mineral and metal products into the United States, whether dutiable or duty-free; the second shows the exports of materials produced in the United States; and the third reports the re-exports of products of foreign origin. These statistics are as reported by the Bureau of Statistics of the Department of Commerce and Labor, and special acknowledgment is due to the Chief of this Bureau, for furnishing the figures for many substances which are not reported in the Monthly Summary. The complete statement of production in the United States is given under the separate chapters.

IMPORTS (*a*)

Year.	Aluminium. Crude.				Ammonium Sulphate.			
	Lb.	Kg.	Value.	Value per Lb.	Lb.	Metric Tons.	Value.	Value per Lb.
1907	872,474	395,754	$181,352	$0.208	70,440,992	31,960	$1,828,236	$0.026
1908	465,317	210,785	80.268	0.173	76,475,104	34,698	1,982,830	0.026
1909	5,109,843	2,317,784	745,963	0.145	85,829,334	38,932	2,114,694	0.024
1910	(*o*)12,271,277	5,567,730	1,844,830	0.151	184,686,534	83,795	4,668,820	0.025
1911	4,173,308	1,893,000	598,272	0.143	189,265,797	85,850	5,066,470	0.027
1912	22,759,937	10,326,650	3,092,889	0.136	119,085,120	54,049	3,447,225	0.029
1913	23,185,775	10,519,861	3,905,977	0.169	130,549,440	59,252	3,957,307	0.030
1914	16,241,340	7,369,029	2,729,383	0.168	166,031,040	75,356	4,475,603	0.027
1915	8,534,834	3,871,375	1,511,988	0.165	72,748,480	33,008	1,934,625	0.027
1916	6,646,385	3,014,734	1,729,298	0.260	29,034,880	13,171	954,815	0.033

Year.	Antimony. (*r*)				Antimony Ore.			
	Lb.	Metric Tons.	Value.	Value per Lb.	Lb.	Metric Tons.	Value.	Value per Lb.
1907....	8,662,683	3,928	$1,423,276	$0.164	2,780,186	1,261	$180,903	$0.065
1908....	8,114,651	3,954	572,979	0.071	3,280,922	1,488	106,930	0.033
1909....	9,652,568	4,335	619,179	0.064	3,386,708	1,575	94,249	0.027
1910....	9,899,514	4,487	572,031	0.058	*Nil.*	....	....	....
1911....	10,957,844	4,970	573,564	0.052	*Nil.*	....	....	....
1912...	17,645,870	8,006	936,920	0.053	*Nil.*	....	....	....
1913....	15,333,492	6,957	878,773	0.057	49,803	221	1,739	0.035
1914....	13,070,381	5,930	737,233	0.056	1,986,082	901	54,408	0.027
1915....	17,484,030	7,933	3,633,420	0.206	3,374,012	1,531	351,540	0.104
1916...	19,749,830	8,958	5,219,885	0.264	9,485,423	4,303	1,049,806	0.111

Year.	Asbestos.			Asphaltum.			
	Crude, Value.	Mfd., Value.	Total Value.	Long Tons.	Metric Tons.	Value.	Value per L. T.
1907 ...	$1,104,109	$200,371	$1,304,480	127,902	129,948	$518,074	$4.05
1908 ...	1,068,342	147,548	.1,215,869	131,862	133,971	587,698	4.45
1909 ...	993,254	240,381	1,233,635	132,807	134,939	646,655	4.87
1910 ...	1,235,170	308,078	1,543,248	166,379	169,041	776,283	4.66
1911 ...	1,413,541	161,442	1,574,983	174,234	177,030	778,185	4.47
1912 ...	1,456,012	363,759	1,819,771	194,775	198,021	919,467	4.72
1913 ..	1,928,705	389,664	2,318,369	193,783	197,012	911,921	4.71
1914. ..	1,407,758	368,344	1,776,102	124,214	126,284	682,748	5.50
1915 ...	1,981,483	137,320	2,118,803	123,436	125,452	680,357	5.51
1916 ...	3,303,470	135,064	3,438,534	131,911	134,035	735,102	5.57

Year.	Arsenic. (b)				Barytes.				Bauxite.			
	Lb.	Metric Tons.	Value.	Value per Lb.	Long Tons.	Metric Tons.	Value.	Value per L. T.	Long Tons.	Metric Tons.	Value.	Value per L. T.
1907....	9,922,870	4,500	$553,440	$0.056	28,350	28,804	$174,225	$6.15	25,065	25,466	$93,208	$3.72
1908....	9,592,881	4,558	417,137	0.056	n)12,196	12,390	58,822	4.83	21,679	22,033	87,823	4,05
1909....	7,183,644	3,259	272,493	0.038	n)13,091	13,301	54,707	4.19	18,989	18,689	83,956	4.49
1910....	8,257,474	3,745	251,716	0.031	n)16,960	17,226	48,457	2.86	14,038	14,258	65,743	4.68
1911....	5,404,263	2,451	159,626	0.030	20,860	21,195	58,726	2.82	43,222	43,916	164,301	3.80
1912....	6,758,946	3,066	246,815	0.037	26,665	27,093	79,315	2.97	26,214	26,635	95,431	3.64
1913....	6,688,216	3,034	285,537	0.043	36,875	37,490	99,564	2.97	21,456	21,814	85,746	3.99
1914....	4,079,372	1,851	165,266	0.040	25,598	26,025	77,265	3.02	24,844	25,258	96,500	3.88
1915....	3,573,624	1,621	154,517	0.043	3,404	3,460	15,613	4.59	3,421	3,477	17,500	5.12
1916....	2,180,321	989	124,844	0.057	146	148	2,317	15.87	30	30	87	2.90

Year.	Bismuth.				Chrome Ore.				Coal, Anthracite.			
	Lb.	Kg.	Value.	Value per Lb.	Long Tons.	Metric Tons.	Value.	Value per L.T.	Long Tons.	Metric Tons.	Value.	Value per L.T.
1907 .	259,881	117,882	$325,015	$1.25	41,999	42,671	$491,925	$11.71	9,896	10,054	$40,966	$4.14
1908 .	164,793	73,002	257,397	1.56	27,876	28,320	345,960	12.40	16,483	16,747	73,777	4.47
1909 .	183,413	83,195	286,516	1.56	39,820	40,459	460,758	11.57	4,709	4,785	19,438	4.13
1910 .	198,174	89,916	332,674	1.67	38,579	39,196	415,768	10.77	8,196	8,327	42,234	5.14
1911 .	172,093	78,061	311,771	1.81	37,529	38,131	407,958	10.87	2,463	2,502	12,550	5.10
1912 .	182,839	82,935	316,440	1.73	53,929	54,828	499,818	9.27	1,670	1,698	8,329	4.99
1913 .	117,747	53,424	213,257	1.81	65,180	66,266	627,821	9.56	921	936	5,697	6.19
1914 .	90,505	41,064	165,248	1.83	74,686	75,931	655,306	8.77	19,347	19,669	37,998	1.96
1915 .	44,362	20,122	108,288	2.44	76,455	77,704	780,061	10.20	2,998	3,047	14,922	4.98
1916 .	76,723	34,801	195,975	2.55	115,886	117,752	1,548,402	13.36	5,693	5,785	19,316	3.39

Year.	Coal, Bituminous.				Total Coal.		Coke.			
	Long Tons.	Metric Tons.	Value.	Value per L. T.	Long Tons.	Value.	Long Tons.	Metric Tons.	Value.	Value per L. T.
1907....	2,116,122	2,149,980	$5,398,167	$2.55	2,126,018	$5,439,133	132,536	134,656	$594,137	$4.48
1908....	1,487,816	1,511,621	4,059,786	2.73	1,504,299	4,133,563	129,591	131,624	603,964	4.65
1909....	1,257,629	1,277,814	3,597,991	2.56	1,262,338	3,617,429	170,671	173,410	735,253	4.31
1910....	1,991,943	2,023,914	5,381,062	2.69	2,000,270	5,423,296	156,417	158,920	625,619	4.00
1911....	1,238,808	1,258,691	3,611,518	2.92	1,241,271	3,624,068	69,515	70,631	254,938	3.67
1912....	1,608,350	1,635,156	4,509,636	2.80	1,610,020	4,517,965	110,347	112,186	488,691	4.43
1913....	1,413,857	1,437,421	3,856,811	2.73	1,414,778	3,862,508	93,507	95,065	442,687	4.73
1914....	1,375,316	1,398,238	3,889,821	2.80	1,394,663	3,927,819	120,777	122,790	555,548	4.60
1915....	1,521,237	1,546,085	4,398,425	2.96	1,524,235	4,413,347	47,520	48,296	222,382	4.68
1916....	1,530,212	1,554,848	4,714,433	3.08	1,535,905	4,733,749	49,067	49,857	249,514	5.09

Year.	Chloride of Lime.				Cement.			
	Lb.	Metric Tons.	Value.	Value per Lb.	Barrels. (c)	Metric Tons.	Value.	Value per Bbl.
1907..........	112,090,783	50,833	$939,248	$0.008	2,006,228	363,929	$2,637,424	$1.31
1908..........	74,602,059	33,848	621,713	0.008	839,246	152,313	1,189,560	1.42
1909..........	91,390,004	41,454	743,636	0.008	431,785	78,342	642,397	1.49
1910..........	101,029,345	45,839	797,260	0.008	292,314	53,053	396,428	1.36
1911..........	82,895,472	37,601	667,804	0.008	163,802	29,720	254,258	1.55
1912..........	74,235,256	33,682	597,002	0.008	65,064	11,808	93,583	1.44
1913..........	61,605,077	27,951	510,120	0.0083	77,333	14,035	134,187	1.74
1914..........	34,539,934	15,671	332,792	0.0096	115,770	20,920	193,155	1.68
1915..........	7,564,473	3,432	102,570	0.0135	40,097	7,275	57,149	1.43
1916..........	1,605,036	728	52,628	0.0328	1,714	311	4,924	2.87

Year.	Cobalt Oxide.				Copper, Ore and Matte.			
	Lb.	Kg.	Value.	Value per Lb.	Long Tons.	Metric Tons.	Value.	Value per L. T.
1907........	42,794	19,421	$73,028	$1.71	291,957	297,096	$9,048,270	$31.32
1908........	1,550	701	3,095	2.00	288,022	292,630	6,978,513	24.20
1909........	9,818	4,453	11,065	1.132	393,530	399,846	9,113,254	23.16
1910........	6,124	2,778	4,806	0.785	453,747	461,007	9,182,161	20.23
1911........	22,934	10,403	11.047	0.482	292,931	297,633	6,935,794	23.68
1912........	31,848	14,446	15,132	0.475	499,549	507,875	12,696,532	25.42
1913........	47,277	21,451	26,154	0.553	511,163	519,682	13,573,327	26.55
1914........	227,886	103,397	220,593	0.97	417,222	424,176	12,172,138	29.17
1915........	154,672	70,159	148,828	0.96	414,423	421,147	13,929,883	33.61
1916........	206,639	93,756	192,009	0.93	631,168	641,330	29,799,581	47.21

Year.	Copper, Ingots, Old, etc.				Cryolite.			
	Lb.	Metric. Tons.	Value.	Value. per Lb.	Long Tons.	Metric Tons.	Value.	Value per L. T.
1907.....	192,901,267	87,523	$38,658,754	$0.200	1,438	1,461	$28,920	$20.10
1908.....	162,224,144	73,604	22,851,134	0.141	1,124	1,142	16,445	14.63
1909.....	240,713,721	109,186	30,529,425	0.127	1,278	1,299	18,427	14.42
1910.....	259,210,796	117,609	31,620,689	0.122	36	......	2,343	......
1911.....	265,940,760	120,630	31,540,827	0.119	2,007	2,039	47,093	23.46
1912.....	305,369,592	138,552	44,259,727	0.145	2,126	2,160	48,293	22.72
1913.....	300,068,849	136,147	44,328,574	0.148	2,559	2,602	52,557	20.54
1914.....	201,549,503	91,447	27,813,866	0.138	4,613	4,690	94,424	20.47
1915.....	201,367.008	91,360	30,617,535	0.152	3,940	4,004	82,750	21.00
1916.....	287,548,126	130,429	65,384,132	0.227	3,857	3,919	165,222	42.84

Year.	Emery Grains.				Emery Rock.			
	Lb.	Metric. Tons.	Value.	Value per Lb.	Long Tons.	Metric Tons.	Value.	Value per L. T.
1907....	4,282,228	1,942	$186,156	$0.043	11,235	11,415	$211,184	$18.80
1908....	1,735,366	788	89,702	0.052	8,084	8,213	146,105	18.09
1909....	2,696,960	1,224	132,264	0.049	9,836	9,993	186,930	19.00
1910....	1,189,664	535	53,709	0.045	16,770	16,321	344,421	20.54
1911....	712,134	323	35,384	0.050	10,232	10,396	176,890	17.29
1912....	791,667	359	32,876	0.042	15,793	16,052	284,585	18.01
1913....	2,496,372	1,133	114,806	0.046	17,122	17,377	342,809	20.03
1914....	761,674	346	30,017	0.039	12,662	12,873	255,554	20.10
1915....	569,639	258	22,655	0.040	8,313	8,449	180,594	21.72
1916....	217,725	99	9,286	0.043	7,511	7,632	102,459	13.64

Year.	Fuller's Earth.		Gold.		Iron Ore.			
	Long Tons.	Value.	In Coin and Bullion.	In Ore.	Long Tons.	Metric Tons.	Value.	Value per L. T.
1907...	14,648	$122,221	$130,605,413	$12,792,659	1,229,168	1,248,835	$3,937,483	$3.20
1908...	10,963	92,413	38,346,267	11,930,026	776,898	789,326	2,224,248	2.86
1909...	11,406	101,151	30,648,147	13,438,819	1,694,957	1,722,161	4,579,078	2.70
1910...	13,775	132,545	47,212,754	12,009,764	2.591,031	2,632,617	7,832,225	3.02
1911...	16,272	143,594	46,623,766	10,821,418	1,811,732	1,840,810	5,412,636	2.99
1912...	17,062	145,337	55,789,906	10,758,866	2,104,576	2,139,652	6,499,690	3.09
1913...	16,632	146,001	51,618,628	12,086,204	2,594,770	2,638,016	8,336,819	3.21
1914...	22,302	195,083	46,311,059	11,076,682	1,350,588	1,373,891	4,483,832	3.32
1915...	17,349	152,493	438,302,822	13,651,768	1,341,281	1,363,189	4,181,645	3.12
1916...	15,001	139,664	672,588,232	13,402,002	1,325,736	1,347,080	4,566,514	3.44

Year.	Phosphates, Crude.				Pig Iron.			
	Long Tons.	Metric. Tons.	Value.	Value per L. T.	Long Tons.	Metric Tons.	Value.	Value per L. T.
1907....	25,876	26,290	$163,944	$6.34	489,475	497,305	$13,418,982	$27.42
1908....	26,734	27,161	175,365	6.56	92,202	93,677	2,886,339	31.35
1909....	11,903	12,094	97,277	8.18	176,442	179,265	5,112,045	28.97
1910....	19,384	19,688	235,040	12.12	237,233	241,029	6,549,938	27.61
1911....	16,153	16,412	157,394	9.74	148,459	150,842	4,380,334	29.50
1912....	28,821	29,284	231,255	8.02	129,325	131,481	4,770,730	36.89
1913....	26,408	26,833	206,719	7.83	156,450	159,058	6,557,095	41.91
1914....	15,178	15,431	136,526	9.00	139,683	141,218	4,694,186	33.60
1915....	5,359	5,446	50,606	9.44	89,836	91,303	4,108,180	45.73
1916....	4,612	4,686	36,389	7.89	135,349	137,528	10,239,868	75.65

Year.	Iron and Steel Scrap.			Bar Iron.		
	Long Tons.	Metric Tons.	Value.	Long Tons.	Metric Tons.	Value.
1907..........	27,652	28,094	$368,842	39,746	40,382	$1,774,441
1908..........	5,090	5,171	61,981	19,671	19,980	837,585
1909..........	63,504	64,523	781,426	19,210	19,518	806,862
1910..........	72,764	73 928	928,002	38,231	38,783	1,565,999
1911..........	17,272	17,549	190,285	26,730	27,159	1,202,363
1912..........	23,612	24,006	256,710	26,112	26,547	1,151,853
1913..........	44,154	44,890	510,707	28,243	28,714	1,340,184
1914..........	34,849	35,430	277,818	15,015	16,688	625,365
1915..........	79,982	81,243	761,719	8,474	8,659	417,491
1916..........	116,039	117,907	1,140,704	7,701	7,825	647,393

Year.	Rails.			Hoop, Band or Scroll.			Ingots, Blooms, Slabs, Billets, etc.		
	Long Tons.	Metric Tons.	Value.	Long Tons.	Metric Tons.	Value.	Long Tons.	Metric Tons.	Value.
1907...	3,752	3,812	$104,958	1,508	1,532	$82,706	(*m*)19,334	19,643	$3,004,178
1908...	1,719	1,752	53,128	1,110	1,127	75,920	11,212	11,391	1,437,514
1909...	1,542	1,567	36,963	(*f*)	(*f*)	(*f*)	19,289	19,599	2,695,630
1910...	(*f*)	(*f*)	(*f*)	(*f*)	(*f*)	(*f*)	46,578	47,323	4,075,036
1911...	(*f*)	(*f*)	(*f*)	(*f*)	(*f*)	(*f*)	29,205	29,687	2,772,614
1912...	3,780	3,843	101,544	(*f*)	(*f*)	(*f*)	18,702	19,014	2,941,481
1913...	10,408	10,581	216,272	(*f*)	(*f*)	(*f*)	26,765	27,202	3,505,463
1914...	22,571	22,947	610,037	648	659	23,702	40,189	40,845	2,943,047
1915...	78,525	79,808	2,088,532	*Nil*	*Nil*	*Nil*	14,998	15,243	1,941,601
1916...	26,299	26,722	740,109	*Nil*	*Nil*	*Nil*	26,142	26,561	3,239,642

Year.	Sheet, Plate and Taggers, Iron or Steel.			Tin Plates, Terne Plates and Taggers Tin.			Wire Rods.		
	Long Tons.	Metric Tons.	Value.	Long Tons.	Metric Tons.	Value.	Long Tons.	Metric Tons.	Value.
1907...	3,749	3,809	$367,140	57,773	58,697	$4,462,522	17,076	17,349	$851,571
1908...	2,628	2,669	377,549	58,492	59,426	3,651,576	11,208	11,387	543,170
1909...	4,711	4,787	536,841	62,593	63,598	3,782,952	10,544	10,613	531,652
1910...	6,107	6,205	461,632	67,086	68,159	4,502,862	20,374	20,700	1,024,831
1911...	2,454	2,495	275,498	14,089	14,324	1,081,864	15,483	15,980	731,291
1912...	3,299	3,354	363,141	2,053	2,087	229,891	15,069	15,320	726,205
1913...	2,893	2,941	381,593	20,680	21,025	1,478,635	16,098	16,366	802,401
1914...	4,310	4,382	514,080	15,411	15,668	1,049,297	6,954	7,070	373,615
1915...	1,416	1,444	218,954	2,350	2,389	196,328	5,317	5,403	331,724
1916...	1,730	1,758	345,622	1,008	1,024	214,574	4,130	4,196	509,559

Year.	Wire and Articles Made from.			Total Iron Imports. (e)	Lead in Ore and Base Bullion.		
	Long Tons.	Metric Tons.	Value.		Short Tons.	Metric Tons	Value.
1907 ...	(f)	(f)	$1,551,415	$38,789,992	70,538	64,019	$3,579,990
1908 ...	(f)	(f)	1,003,973	19,957,385	109,315	99,168	4,384,904
1909 ...	(f)	(f)	1,117,812	30,571,542	110,605	100,339	4,121,380
1910 ...	(f)	(f)	1,468,741	47,115,112	105,117	106,805	4,056,722
1911 ...	(f)	(f)	1,270,426	28,995,600	87,319	79,215	3,452,695
1912 ...	(f)	(f)	1,103,192	29,328,709	83,288	75,576	3,721,583
1913 ...	(f)	(f)	1,167,368	33,601,985	57,105	51,817	2,962,139
1914 ...	(f)	(f)	1,205,456	28,642,862	28,190	25,580	1,867,064
1915 ...	(f)	(f)	640,521	20,380,093	51,086	46,358	3,431,829
1916 ...	(f)	(f)	652,889	27,986,951	29,674	26,921	2,933,022

Year.	Lead in Pigs and Old.			Lead, Sheet, Pipe, Shot, etc.			Other Lead Mfrs.	Total Lead.
	Short Tons.	Metric Tons.	Value.	Lb.	Metric Tons.	Value.		
1907..........	9,277	8,414	$846,166	734,418	333	$39,210	$12,736	$4,426,156
1908..........	2,759	2,504	182,503	42,376	19	2,026	46,486	4,567,407
1909..........	3,576	3,244	230,347	40,434	18	2,056	33,892	4,351,727
1910..........	3,491	3,166	202,376	(f)	....	....	7,073	4,259,098
1911..........	2,632	2,388	190,543	(f)	....	....	9,834	3,642,238
1912..........	272	247	19,917	31,284	14	2,305	7,328	3,748,828
1913..........	41	37	3,678	(f)	(f)	(f)	17,138	2,982,955
1914..........	148	134	10,082	(f)	(f)	(f)	83,672	1,960,818
1915..........	410	372	28,154	201,510	91	17,059	131,635	3,591,618
1916..........	5,655	5,773	761,537	532	....	63	106,119	3,800,678

Year.	White Lead.				Litharge.				Red Lead.			
	Lb.	Metric Tons.	Value.	Value per lb.	Lb.	Metric Tons.	Value.	Value per lb.	Lb.	Metric Tons.	Value.	Value per lb.
1907...	584,309	265	$37,482	$0.064	90,475	41	$4,386	$0.048	679,171	308	$35,959	$0.053
1908...	540,311	245	30,451	0.056	96,184	44	3,327	0.035	645,073	292	28,155	0.034
1909...	694,599	315	39,963	0.057	90,655	32	3,740	0.041	760,179	345	30,428	0.040
1910...	686,052	311	38,919	0.057	48,693	22	2,252	0.046	822,289	373	32,750	0.039
1911...	741,071	336	46,213	0.062	24,662	11	1,196	0.048	1,163,533	528	46,170	0.040
1912. .	687,705	312	46,494	0.068	32,443	15	1,550	0.048	757,908	344	33,854	0.045
1913...	671,839	305	48,266	0.072	34,023	15	1,750	0.051	99,562	45	4,903	0.049
1914...	707,774	321	50,989	0.072	33,651	15	1,805	0.054	6,014	3	260	0.044
1915...	339,157	154	24,608	0.073	20,650	9	1,422	0.069	1,968	1	132	0.067
1916...	88,617	40	8,050	0.091	1,320	1	150	0.114	20,467	9	5,302	0.259

Year.	Orange Mineral.				Magnesite.			
	Lb.	Metric Tons.	Value.	Value per Lb.	Long Tons.	Metric Tons.	Value.	Value per L.T.
1907.....	615,015	279	$37,793	$0.061	88,400	89,814	$875,359	$9.90
1908.....	485,407	220	26,645	0.055	75,442	76,648	736,763	9.80
1909.....	496,231	225	27,562	0.056	102.045	103,683	985,019	9.66
1910.....	600,461	269	32,199	0.053	152,078	154,511	1,542,800	10.14
1911.....	504,734	229	28,515	0.056	120,133	122,061	1,185,867	9.85
1912.....	334,551	152	20,914	0.063	123,801	125,788	1,369,665	11.06
1913.....	330,525	150	22,205	0.067	161,012	163,696	1,757,476	10.92
1914.....	240.388	109	16,388	0.068	120,688	122.699	1,427,772	11.83
1915.....	171,572	78	14,061	0.082	68,159	69,272	647,241	9.41
1916.....	70,934	32	8,781	0.124	75,549	76,765	838,630	11.10

Year.	Manganese Ore.				Mica.	Nickel. (h)	Nickel Ore and Matte.		
	Long Tons.	Metric Tons.	Value.	Value per L. T.			Long Tons.	Metric Tons.	Value.
1907.....	209,021	211,236	$1,793,143	$8.59	$915,259	$90,153	16,888	17,158	$2,153,971
1908.....	178,023	181,054	1,350,223	7.59	264,755	101,398	16,322	16,582	2,396,217
1909.....	212,765	216,180	1,405,329	6.60	493,978	104,019	18,578	18,876	2,927,975
1910.....	242,348	246,226	1,711,131	7.06	721,541	139,772	28,519	28,975	4,085,076
1911.....	176,852	179,690	1,186,791	6.71	469,089	104,160	23,993	24,378	3,918,556
1912.....	300,661	305,672	1,769,184	5.84	745,399	120,511	33,101	33,653	5,638,456
1913.....	345,090	350,842	2,029,680	5.87	981,601	(f)	37,623	38,250	6,427,639
1914.....	283,294	288,016	2,024,120	5.88	204,850	(f)	29,564	30,056	4,956,448
1915.....	313,985	319,040	2,633,286	8.40	244,292	19,929	45,798	46,546	7,615,999
1916	576,321	585,600	8,666,179	15.04	1,126,271	36,098	59,741	60,703	9,889,122

Year.	Oil, Mineral.			Platinum, Unmanufactured.				Platinum Mfrs.
	Gal.	Value.	Value per Gal.	Lb. Troy.	Kg.	Value.	Value per Lb. Troy.	
1907....	20,505,197	$1,037,728	$0.051	7,515	2,805	$2,509,926	$333.99	$175,651
1908....	9,289,376	393,050	0.042	4,155	1,551	1,096,615	263.92	134,119
1909....	3,862,445	198,540	0.051	9,904	3,696	2,557,574	258.30	410,997
1910....	24,323,829	1,438,609	0.059	10,009	3,736	3,320,699	331.77	1,717,584
1911....	69,019,304	2,406,581	0.035	2,868	1,070	1,278,293	445.71	3,587,998
1912....	309,765,930	6,033,231	0.019	3,692	1,378	1,716,630	464.96	2,777,853
1913....	731,360,523	12,997,011	0.018	4,283	1,599	1,978,770	462.01	3,065,489
1914....	724,446,909	11,500,730	0.016	2,676	999	1,154,955	431.60	1,818,668
1915....	763,705,698	10,563,628	0.014	4,644	1,733	2,077,536	447.35	334,472
1916....	890,853,850	13,887,263	0.016	3,436	1,283	2,506,531	729.49	650,788

Year.	Potassium Salts.											
	Chlorate.			Chloride.			Chromate and Bi-chromate.			Nitrate.		
	Lb.	Value.	Value per Lb.	Lb.	Value.	Value per Lb.	Lb.	Value.	Value per Lb.	Lb.	Value.	Value per Lb.
		$	$		$	$		$	$		$	$
1907....	12,980	959	0.074	252,303,441	4,175,353	0.017	18,171	1,307	0.072	18,291,890	574,977	0.031
1908....	17,607	1,447	0.082	214,338,887	3,415,326	0.016	216,080	15,453	0.072	16,118,160	470,116	0.029
1909....	22,425	1,837	0.082	298,854,649	4,780,106	0.016	640,623	31,798	0.050	14,883,849	437,690	0.027
1910....	410,770	26,313	0.064	381,873,875	5,252,373	0.014	406,791	19,569	0.048	11,496,904	333,854	0.029
1911....	27,856	2,450	0.088	509,119,193	7,651,684	0.015	22,408	2,159	0 096	7,945,747	265,061	0.038
1912....	99,919	6,787	0.068	482,265,665	7,229,109	0.015	32,913	3,085	0.094	7,315,531	216,492	0.030
1913....	1,191,461	64,468	0.054	478,826,857	7,120,055	0.015	18,629	1,819	0.097	9,876,910	262,575	0.027
1914....	27,406	2,235	0.083	371,520,195	5,745,385	0.015	31,858	2,375	0.075	2,229,856	74,743	0.034
1915....	16,001	3,666	0.229	129,346,560	2,297,149	0.018	32,942	2,902	0.088	127,270	28,095	0.022
1916....	10,199	7,189	0.705	2,598,400	348,961	0.134	459	75	0.163	11,537,033	1,519,375	0.131

Year	Potassium Salts, All Other. (s)		Precious Stones. (t)			Pyrite. (i)			
	Lb.	Value.	Uncut.	Cut, not Set.	Jewelry.	Long Tons.	Metric Tons.	Value.	Value per L. T.
1907.	91,299,496	$2,220,685	$8,740,278	$23,706,975	$1,069,373	256,479	666,981	$2,637,485	$4.01
1908.	69,382,278	1,721,626	2,367,189	11,660,442	720,502	668,115	678,804	2,624,339	3.93
1909.	100,180,417	2,445,526	9,230,287	34,340,269	1,267,457	692,385	703,498	2,428,638	3.51
1910.	116,820,873	2,777,396	9,426,647	32,424,471	1,907,148	806,590	819,495	2,773,627	3.46
1911.	155,140,643	3,909,361	9,963,393	30,224,826	1,470,167	1,001,944	1,018,025	3,788,632	3.78
1912.	131,049,932	3,185,098	9,979,582	26,218,261	989,288	964,478	980,553	3,860,738	3.88
1913.	124,519,551	3,253,245	12,630,037	27,626,937	998,723	848,674	862,819	3,611,136	4.00
1914.	....	....	3,008,823	13,652,861	775,364	977,372	993,662	4,706,383	4.82
1915.	41,109,008	1,461,637	7,124,316	14,161,769	387,150	974,616	990,531	4,817,977	4.95
1916.	6,578,291	449,538	11,459,508	26,420,425	307,510	1,244,519	1,264,556	6,728,318	5.41

Year.	Salt.				Silver.		Sodium Nitrate.			
	Short Tons.	Metric Tons.	Value.	Value per Sh. T.	In Coin and Bullion.	In Ore.	Long Tons.	Metric Tons.	Value.	Value per L. T.
1907..	153,435	139,166	$452,227	$2.95	$17,652,679	$28,259,681	364,610	370,444	$14,844,675	$40.71
1908..	156,608	142,043	440,484	2.81	14,169,524	28,054,606	310,713	315,684	11,385,393	36.68
1909..	158,487	143,777	447,983	2.83	15,728,756	30,458,946	428,429	435,569	13,608,195	31.43
1910..	142,549	129,320	388,015	2.72	15,913,668	29,964,500	529,172	605,938	16,601,328	31.37
1911..	137,759	124,974	378,083	2.74	16,351,154	27,395,417	544,878	553,623	16,814,256	30.86
1912..	136,391	123,762	361,664	2.65	24,053,983	24,347,103	486,352	494,458	16,554,104	34.04
1913..	150,602	136,609	416,375	2.77	19,979,971	15,887,848	625,862	636,293	21,630,811	34.56
1914..	130,752	118,649	385,752	2.95	18,941,980	7,017,207	541,715	552,777	15,228,671	28.01
1915..	123,576	112,138	366,475	2.97	26,375,801	8,108,163	772,190	784,803	22,959,997	29.73
1916..	121,967	110,648	342,588	2.81	13,615,185	18,648,104	1,218,423	1,238,041	38,131,962	31.29

Year.	Sodium Hydroxide (Caustic).			Soda Ash and Carbonate.			All other Sodium Salts.	
	Lb.	Value.	Value. per Lb.	Lb.	Value.	Value per Lb.	Lb.	Value.
1907 ..	1,297,070	$37,894	$0.029	6,198,136	$66,521	$0.011	8,481,979	$258,262
1908 ..	874,813	26,079	0.029	3,515,933	38,372	0.011	....	296,777
1909 ..	942,982	29,771	0.032	153,928	3,543	0.023	13,805,869	350,396
1910. .	2,973,522	70,901	0.027	314,396	4,269	0.014	35,895,668	406,643
1911. .	990,562	34,281	0.035	3,214,129	36,252	0.011	22,202,439	303,934
1912. .	884,204	29,461	0.033	3,393,354	39,912	0.012	7,332,392	232,808
1913 ..	696,158	25,888	0.037	2,962,180	35,872	0.012	7,518,125	263,162
1914 ..	535.883	21,607	0.040	3,130,366	51,869	0.017	....	....
1915 ..	244,806	15,058	0.062	838,609	13,369	0.016	....	....
1916 ..	154,223	24,606	0.160	1,015,010	29,134	0.029	3,557,120	564,473

Year.	Sulphur.									
	Crude.				Flowers.			Refined.		
	Long Tons.	Metric Tons.	Value.	Value per L. T.	Long Tons.	Metric Tons.	Value.	Long Tons.	Metric Tons.	Value.
1907 ..	20,399	20,725	$355,944	$17.45	1,458	1,481	$41,216	606	616	$14,589
1908 ..	20,118	20,441	318,577	15.83	793	804	22,562	692	700	17,227
1909 ..	26,914	27,346	458,954	17.05	770	782	23,084	966	982	26,021
1910 ..	28,647	29,105	495,988	17.31	915	930	30,180	990	1,004	25,869
1911 ..	24,250	24,639	436,725	18.01	3,891	3,953	83,491	986	1,002	24,906
1912 ..	26,885	27,333	494,778	18.40	1,310	1,331	39,126	1,665	1,692	40,933
1913 ..	14,636	14,880	278,056	19.00	5,899	5,997	115,574	1,233	1,254	29,091
1914 ..	22,810	23,190	409,537	18.39	621	631	17,214	1,800	1,830	47,568
1915 ..	24,647	25,050	405,990	16.43	647	658	23,046	988	1,004	30,335
1916 ..	21,289	21,632	358,416	16.84	425	432	18,408	455	462	15,020

Year.	Talc.				Tin.			
	Short Tons.	Metric Tons.	Value.	Value per Sh. T.	Lb.	Metric Tons.	Value.	Value per Lb.
1907 ...	10,060	10,221	$126,391	$12.56	82,548,838	37,436	$32,075,091	$0.389
1908 ...	7,429	6,738	97,296	13.08	82,503,190	37,433	23,932,560	0.290
1909 ...	8,377	7,599	102,964	12.29	95,350,020	43,250	27,559,937	0.289
1910 ...	8,378	7,560	106,451	12.72	105,137,740	47,703	33,921,449	0.322
1911 ...	7,113	6,453	88,050	12.38	106,936,872	48,506	43,390,639	0.406
1912 ...	10,817	9,813	121,541	11.24	116,003,385	52,633	50,371,102	0.434
1913 ...	14,004	12,702	143,500	10.25	104,282,230	47,315	46,900,314	0.450
1914 ...	17,869	16,210	202,415	11.33	95,049,612	43,126	32,861,188	0.346
1915 ...	18,069	16,396	199,840	11.06	115,636,332	52,465	38,736,909	0.336
1916 ...	16,682	15,134	218,180	13.08	138,073,293	62,629	51,803,384	0.375

Year.	Zinc.								
	Blocks, Pigs and Old.				Oxide. (j)		Sulphide.		Mfrs.
	Lb.	Metric Tons.	Value.	Value. per Lb.	Lb.	Value.	Lb.	Value.	Value.
1907	3,555,890	1,613	$210,322	$0.059	5,311,318	$323,551	1,570,073	$51,435	$16,282
1908	1,762,627	799	85,885	0.049	4,635,101	262,876	1,048,109	46,733	7,474
1909	19,340,029	8,772	826,588	0.043	6,654,352	397,084	1,263,316	44,873	19,176
1910	6,904,389	3,133	289,689	0.042	6,470,097	391,670	3,726,135	99,954	27,475
1911	3,275,340	1,486	170,634	0.052	5,561,016	357,466	6,355,312	166,199	124,983
1912	22,229,831	10,086	1,280,426	0.058	5,875,057	386,153	5,904,475	153,303	293,089
1913	12,199,267	5,535	660,706	0.054	6,865,094	433,886	5,066,535	152,980	62,256
1914	1,759,579	798	71,165	0.040	5,258,108	302,838	9,072,567	277,862	31,724
1915	1,808,964	821	131,468	0.072	1,764,887	154,149	4,251,772	144,567	15,753
1916	1,368,560	621	119,000	0.087	930,267	185,395	63,419	8,862	1,205

(*a*) From Summary of Commerce and Finance of the United States. (*b*) Includes arsenic sulphide. (*c*) Barrels of 400 lb. (*e*) Not including iron ore. (*f*) Not reported. (*h*) Includes nickel oxide, alloys in which nickel is the principal constituent, and manufactures of nickel. (*i*) Containing more than 25 per cent. sulphur. (*j*) Includes white pigments containing zinc but not lead, dry and in oil. (*m*) Includes bars of steel and steel forms not elsewhere specified. The high value is due to the value of "high-speed" steel. (*n*) Crude. (*o*) Crude, scrap and alloys in which aluminum is chief component. (*r*) Antimony contents of ores, regulus and metal. (*s*) Not kainit. (*t*) Exclusive of pearls.

EXPORTS OF DOMESTIC PRODUCTS (*a*)

Year.	Aluminium and Mfrs. of.	Asbestos and Mfrs. of.	Cement.			
			Bbl.(*i*)	Metric Tons.	Value.	Value per Bbl.
1907	$304,938	$200,371	900,550	163,360	$1,450,841	$1.61
1908	330,092	296,890	846,785	153,638	1,249,229	1.47
1909	567,375	322,523	1,056,922	191,764	1,417,534	1.34
1910	949,215	348,716	2,475,957	449,314	3,477,981	1.40
1911	1,158,603	448,395	3,135,409	568,886	4,632,215	1.48
1912	1,347,621	601,701	4,215,532(*p*)	726,606	6,160,341	1.46
1913	966,094	754,102	2,964,358(*p*)	510,949	4,270,666	1.44
1914	1,546,510	513,037	2,140,197(*p*)	364,414	3,088,809	1.44
1915	3,682,117	764,050	2,565,031(*p*)	442,119	3,361,451	1.31
1916	15,417,134	1,215,209	2,563,976(*p*)	441,937	3,828,231	1.49

Year	Coal.									
	Anthracite.				Bituminous.				Coke.	
	Long Tons.	Metric Tons.	Value.	Value per L. T.	Long Tons.	Metric Tons.	Value.	Value per L.T.	Long Tons.	Value.
1907	2,698,072	2,741,241	$13,217,985	$4.90	(*m*)10,454,677	10,621,950	(*m*)$26,982,111	$2.54	874,689	$3,206,791
1908	2,752,358	2,796,394	13,524,595	4.92	(*m*) 9,100,819	9,246,431	(*m*) 23,361,914	2.53	620,923	2,161,032
1909	2,842,714	2,888,340	14,141,468	4.97	(*m*) 9,693,843	9,849,429	(*m*) 24,300,050	2.51	895,461	3,232,673
1910	3,021,627	3,070,124	14,785,387	4,89	(*m*)10,784,239	10,957,326	(*m*) 26,685,405	2.47	879,073	3,053,293
1911	3,553,999	3,611,041	18,093,285	5.09	(*m*)13,878,754	14,101,508	(*m*) 34,499,989	2.49	914,042	3,215,490
1912	3,688,789	3,750,268	19,425,263	5.27	(*m*)14,459,978	14,700,978	(*m*) 36,817,633	2.55	814,800	3,002,742
1913	4,154,386	4,224,625	21,959,850	5.29	(*m*)17,986,757	18,286,536	(*m*) 45,449,664	2.53	881,603	3,309,930
1914	3,830,244	3,894,081	20,211,072	5.28	(*m*)13,801,850	14,031,881	(*m*) 34,104,903	2.47	592,487	2,233,686
1915	3,540,406	3,597,407	18,429,255	5.21	(*m*)16,764,857	17,034,771	(*m*) 42,817,341	2.55	799,562	3,092,498
1916	4,165,679	4,232,746	22,470,147	5.39	(*m*)18,977,346	19,282,881	(*m*) 45,828,092	2.41	1,048,790	4,202,236

Year.	Copper.									
	In Ore and Matte.				Ingots, Bars, Plates and Old.				Mfrs.	Total, Except Ore.
	Long Tons.	Metric Tons.	Value.	Value per L. T.	Lb.	Metric Tons.	Value.	Value per Lb.	Value.	
1907	99,141	100,727	$2,452,562	$24.74	508,929,401	230,799	$94,912,185	$0.186	$5,888,170	100,800,355
1908	63,149	64,158	1,254,172	19.87	661,876,127	300,302	87,393,200	0.132	3,162,303	90,555,503
1909	59,880	60,841	1,335,316	22.29	682,846,726	309,734	89,367,455	0.131	3,217,185	92,584,640
1910	43,784	44,585	1,049,086	23.96	695,107,043	315,384	88,949,799	0.128	5,132,287	94,082,086
1911	57,915	58,844	2,352,080	40.61	786,553,208	356,778	98,168,182	0.122	5,159,664	103,327,346
1912	66,171	67,274	3,203,220	48.41	775,000,658	351,634	123,007,884	0.159	3,762,283	126,770,167
1913	65,684	66,779	2,973,997	45.28	926,241,092	420,255	143,353,624	0.155	1,555,493	144,909,117
1914	43,529	44,254	1,606,855	36.91	840,080,922	381,162	116,026,290	0.138	1,162,060	117,188,350
1915	57,731	58,660	453,125	7.85	681,917,955	309,311	117,250,816	0.172	7,885,472	125,136,278
1916	105,847	107,551	1,239,067	11.71	784,103,644	356,660	204,968,673	0.261	25,708,092	230,676,765

Year.	Gold.		Iron.							
			Ore.				Pig.			
	In Coin and Bullion. (*c*)	In Ore. (*d*)	Long Tons.	Metric Tons.	Value.	Value per L.T.	Long Tons.	Metric Tons.	Value.	Value per L. T,
1907	$54,869,688	$345,993	278,208	282,659	$763,422	$2.74	73,703	74,879	$1,508,938	$20.43
1908	80,778,091	437,365	309,099	314,043	1,012,924	3.29	46,696	47,441	789,318	16.92
1909	132,349,610	540,211	455,934	463,251	1,365,325	2.99	61,989	62,994	1,030,267	16.66
1910	54,968,487	470,062	644,875	655,193	2,074,164	3.22	127,385	129,423	2,113,036	16.51
1911	34,488,840	499,265	768,386	780,719	2,653,448	3.45	120,799	122,738	1,874,401	15.52
1912	43,921,951	470,333	1,195,742	1,215,671	3,537,289	2.96	272,676	277,221	3,832,765	13.84
1913	88,331,790	602,781	1,042,151	1,059,520	3,513,419	3.37	277,648	282,275	4,026,306	14.50
1914	220,409,005	285,038	551,618	560,812	1,794,193	3.20	114,423	116,330	1,638,102	14.32
1915	18,902,237	419,330	707,641	719,034	2,181,629	3.08	224,509	226,891	3,667,167	16.33
1916	155,484,759	308,168	1,183,952	1,203,014	3,692,496	3.12	612,241	622,098	15,317,085	25.02

Year.	Iron, Bar.				Iron, Band, Hoop and Scroll.			Billets, Ingots and Blooms.			
	Long Tons.	Metric Tons.	Value.	Value per L. T.	Long Tons.	Metric Tons.	Value.	Long Tons.	Metric Tons.	Value.	Value per L. T.
1907	24,190	24,577	$1,092,631	$45.17	8,587	8,724	$395,758	79,991	81,271	$2,013,319	$25.17
1908	8,224	8,355	362,909	44.12	4,334	4,402	223,073	112,177	113,390	2,674,524	23.84
1909	13,536	13,755	538,436	39.77	3,856	3,918	200,379	104,862	106,545	2,401,091	22.90
1910	18,045	18,234	726,300	40.25	(*n*)	(*n*)	(*n*)	58,230	59,162	1,274,732	21.89
1911	17,683	17,967	653,320	36.94	3,731	3,791	163,853	234,267	238,027	5,150,518	21.99
1912	21,926	22,291	841,824	38.39	12,557	12,766	539,354	294,818	299,732	6,615,131	22.44
1913	16,615	16,892	768,501	46.25	16,841	17,122	767,631	91,847	93,378	2,200,248	23.96
1914	5,226	5,313	203,835	39.00	9,954	10,120	457,451	50,496	51,338	1,103,702	21.86
1915	39,726	40,375	1,471,466	37.04	29,250	29,721	1,433,879	560,704	569,721	14,176,528	25.28
1916	74,069	75,258	3,913,847	52.83	43,208	43,904	3,251,882	1,508,727	1,533,018	90,165,269	59.70

Year.	Iron, Nails and Spikes, Cut.				Iron, Nails and Spikes, All Other.				Iron, Plates and Sheets.		
	Lb.	Metric Tons.	Value	Value per Lb.	Lb.	Metric Tons.	Value.	Value per Lb.	Long Tons.	Met. Tons.	Value.
1907	15,521,208	7,042	$354,802	$0.023	111,670,147	50,642	$3,014,863	$0.027	40,651	41,301	$2,902,025
1908	15,721,898	7,133	364,202	0.023	71,427,124	32,407	1,813,784	0.025	44,100	44,805	2,985,538
1909	22,256,458	10,095	456,635	0.021	85,387,006	38,731	1,993,142	0.023	75,305	76,513	4,706,592
1910	18,208,116	8,261	361,838	0.020	118,881,375	53,939	2,693,753	0.023	102,534	104,175	6,412,458
1911	25,585,379	11,605	470,515	0.018	148,875,384	67,529	3,279,105	0.022	134,497	137,113	8,353,089
1912	20,856,790	9,463	359,962	0.017	186,646,470	84,685	3,976,571	0.021	193,719	196,948	11,844,767
1913	8,488,503	3,851	165,068	0.019	132,014,432	59,898	3,031,967	0.023	98,978	100,628	6,568,413
1914	7,667,552	3,479	142,285	0.019	103,535,214	46,953	2,264,031	0.022	48,818	48,018	3,128,184
1915	9,487,774	4,304	190,667	0.020	255,562,644	11,592	6,048,240	0.024	101,449	103,082	6,603,002
1916	10,645,098	4,828	312,195	0.029	417,489,036	18,937	13,920,560	0.033	131,706	133,826	11,479,046

Year.	Steel, Sheets and Plates.			Iron Rails.				Steel Rails.			
	Long Tons.	Metric Tons.	Value.	Long Tons.	Metric Tons.	Value.	Value per L. T.	Long Tons.	Metric Tons.	Value.	Value per L. T.
1907	82,045	83,358	$4,262,582	*Nil.*	....	....	....	338,906	344,328	$10,411,072	$30.72
1908	60,893	61,865	3,422,031	*Nil.*	....	....	....	196,510	199,654	6,021,549	30.62
1909	104,742	106,423	4,627,614	*Nil.*	....	....	....	299,540	304,533	8,519,793	28.44
1910	171,982	174,734	7,514,832	*Nil.*	....	....	....	353,180	358,831	10,162,522	28.77
1911	237,428	241,239	9,800,215	*Nil.*	....	....	....	420,874	427,629	12,229,045	29.05
1912	352,802	358,682	14,508,622	*Nil.*	....	....	....	446,473	453,914	13,053,774	29.24
1913	364,448	370,522	14,472.711	*Nil.*	....	....	....	460,553	468,229	13,979,549	30.35
1914	232,078	235,946	9,308,312	*Nil.*	....	....	....	174,680	177,591	5,103,918	29.22
1915	318,154	323,276	11,764,484	*Nil.*	....	....	....	391,379	397,680	12,095,170	30.90
1916	339,112	344,572	23,056,571	*Nil.*	....	....	....	540,349	549,049	20,393,449	37.74

Year.	Structural Iron and Steel.				Wire.				Steel Wire Rods.			
	Long Tons.	Metric Tons.	Value.	Value per L.T.	Long Tons.	Metric Tons.	Value.	Value per L. T.	Long Tons.	Metric Tons.	Value.	Value per L. T
1907 .	138,442	140,657	$7,784,618	$56.23	161,228	163,808	$9,164,829	$56.84	10,653	10,823	$465,757	43.72
1908 .	116,878	118,746	6,289,610	53.80	136,167	138,344	7,270,794	53.35	7,412	7,530	277,694	37.39
1909 .	90,830	92,288	4,488,197	49.42	149,341	151,738	7,836,564	52.49	20,142	20,465	635,409	31.56
1910 .	146,721	149,069	7,127,673	48.58	171,928	174,679	9,198,005	53.49	22,869	23,235	714,553	31.25
1911 .	223,493	227,080	10,270,977	45.96	229,762	233,452	11,637,596	50.65	22,641	23,003	659,066	29.10
1912 .	288,164	292,967	12,694,804	44.05	244,711	248,790	11,536,442	47.14	64,978	66,061	1,898,986	29.22
1913 .	403,264	409,985	17,790,744	44.12	190,284	193,455	9,237,541	48.55	61,637	62,664	1,815,922	29.46
1914 .	182,395	185,435	6,961,636	38.17	180,842	183,856	8,568,589	47.38	61,856	62,887	1,810,389	29.27
1915 .	232,139	235,876	8,960,411	38.46	473,583	481,208	25,833,607	54.55	165,014	167,670	4,713,109	39.14
1916 .	301,649	306,506	17,710,698	58.71	683,025	694,028	52,224,940	76.46	158,284	160,832	8,109,111	51.23

Year.	Lead and Mfrs. of.	Nickel. (*e*)	Petroleum products. (In Thousands of Units.)*								
			Crude.			Naphtha.			Illuminating Oil.		
			M Gals.	M Value.	Value per Gal.	M Gals.	M Value.	Value per Gal.	M Gals.	M Value.	Value per Gal.
1907...	$686,096	$2,845,663	126,306	$6,334	$0.050	34,625	$3,676	$0.106	905,924	$59,635	$0.066
1908...	599,640	3,297,988	149,190	6,520	0.044	43,887	4,543	0.103	1,129,005	75,988	0.067
1909...	509,542	4,101,976	186,305	6,568	0.035	68,759	5,800	0.084	1,046,401	67,814	0.065
1910...	614,158	4,704,088	180,111	5,404	0.029	100,695	8,407	0.083	940,247	55,642	0.059
1911...	680,419	8,283,777	201,843	6,165	0.030	137,295	11,483	0.084	1,112,295	61,055	0.055
1912...	651,459	8,515,332	188,711	6,770	0.036	186,000	20,459	0.110	1,026,138	62,084	0.061
1913...	738,135	9,686,794	194,570	8,448	0.043	188,043	28,092	0.149	1,119,441	72,042	0.064
1914...	5,519,908	9,455,528	124,736	4,959	0.040	209,693	25,288	0.121	1,010,449	64,113	0.063
1915...	11,758,979	10,128,514	158,263	4,283	0.027	281,609	33,885	0.120	836,959	49,989	0.059
1916...	17,095,451	12,952,493	172,029	7,031	0.041	356,217	68,671	0.192	854,403	55,845	0.065

Year.	Petroleum Products. (In Thousands of Units.)*									
	Lubricating Oil.			Residue, Etc. (*g*)			Paraffin.			
	M Gals.	M Value.	Value per Gal.	M Gals.	M Value.	Value per Gal.	M Lb.	M Metric Tons.	M Value.	Value per Lb.
1907 ...	152,029	$19,210	$0.126	75,775	$2,528	$0.033	207,504	94.1	$10,209	$0.049
1908 ...	147,769	18,971	0.128	77,552	2,793	0.036	141,667	64.2	6,923	0.049
1909 ...	161,640	20,076	0.124	107,999	3,640	0.034	181,328	82.6	7,609	0.042
1910 ...	163,832	20,291	0.125	117,605	3,732	0.032	199,913	90.7	7,329	0.037
1911 ...	183,320	23,337	0.127	133,979	3,882	0.029	214,018	97.1	7,048	0.033
1912 ...	216,393	28,297	0.131	266,237	6,599	0.025	294,591	133.7	9,603	0.033
1913 ...	207,639	29,609	0.143	426,872	11,126	0.026	236,046	107.1	8,177	0.035
1914 ...	191,648	26,316	0.137	703,508	19,224	0.027	188,823	85.7	6,435	0.034
1915 ...	239,679	32,460	0.135	812,216	22,325	0.028	386,014	175.5	12,535	0.032
1916 ...	260,779	43,022	0.165	961,061	27,163	0.028	376,893	171.0	14,820	0.039

* For convenience in tabulating, the quantities of all petroleum products and their gross values have been divided by 1000.

Year.	Crude Phosphates.				Quicksilver.			Silver.	
	Long Tons.	Metric Tons.	Value.	Value per L.T.	Lb.	Metric Tons.	Value.	In Coin and Bullion (*c*)	In Ore (*d*)
1907....	1,018,212	1,034,503	$8,387,176	$8.24	384,913	174	$192,094	$61,202,024	$423,842
1908....	1,196,175	1,215,374	9,371,649	7.83	224,692	102	124,960	51,554,414	283,257
1909....	1,020,556	1,036,936	7,644,368	7.49	510,241	231	266,243	56,876,292	716,017
1910....	1,083,037	1,100,366	8,234,276	7.63	144,237	65	91,077	53,298,048	346,735
1911....	1,246,577	1,266,585	9,235,388	7.41	21,841	10	13,995	59,756,121	129,909
1912....	1,206,520	1,226,629	8,996,456	7.46	23,283	11	13,360	66,846,486	137,752
1913 . . .	1,366,508	1,389,283	9,996,580	7.32	85,521	39	43,574	59,509,520	154,769
1914....	964,114	980,183	6,771,652	7.02	108,426	49	70,753	47,767,578	76,084
1915....	253,421	257,501	1,603,851	6.33	252,852	115	225,509	47,403,607	63,628
1916....	243,843	247,769	1,158,941	4.75	666,027	302	670,475	70,550,279	44,758

Year.	Zinc Ore.				Zinc, Pigs, Bars, Plates and Sheet.			
	Long. Tons.	Metric Tons.	Value.	Value Per L.T.	Lb.	Metric Tons.	Value.	Value. per Lb.
1907	18,171	18,462	$579,490	$31.89	1,126,753	511	$75,194	$0.067
1908	23,311	23,683	877,745	37.61	5,280,344	2,396	250,254	0.047
1909	11,121	11,299	412,300	37.01	5,131,360	2,328	263,010	0.051
1910	17,599	17,881	649,425	36.90	7,979,457	3,620	426,500	0.053
1911	16,322	16,584	642,884	39.39	13,744,212	6,234	810,099	0.059
1912	20,847	21,194	823,997	39.53	13,268,186	6,020	864,292	0.065
1913	15,815	16,079	631,991	40.00	15,565,324	7,062	955,667	0.061
1914	9,920	10,085	388,464	39.06	129,694,022	58,804	8,540,668	0.066
1915	743	755	35,276	47.48	251,348,910	114,008	31,556,838	0.125
1916	70	71	3,992	57.03	412,732,281	187,211	59,393,028	0.144

Year.	Zinc Oxide.			
	Lb.	Metric Tons.	Value.	Value per Lb.
1907	26,512,920	12,023	$1,069,924	$0.040
1908	24,016,254	10,893	845,070	0.035
1909	26,691,347	13,468	1,026,377	0.035
1910	26,333,993	11,949	943,968	0.036
1911	29,236,779	13,262	1,051,311	0.036
1912	34,128,163	15 484	1,247,702	0.037
1913	28,932,953	13,127	1,136,257	0.039
1914	31,183,369	14,148	1,408,525	0.045
1915	39,978,569	18,134	2,068,428	0.052
1916	27,923,712	12,666	2,394,739	0.086

RE-EXPORTS OF FOREIGN PRODUCTS (*a*)

Year.	Antimony.			Antimony Ore.			Asphaltum, Crude.		
	Lb.	Metric Tons.	Value.	Short Tons.	Metric Tons.	Value.	Long Tons.	Metric Tons.	Value.
1907	47,999	21.8	$9,064	6	5	$273	8,288	8,421	$31,749
1908	1,763	0.8	125	4.8	4.3	663	4,262	4,290	21,419
1909	6,648	3.0	475	0.25	0.23	56	6,867	6,977	48,375
1910	339,685	154.1	20,392	*Nil.*	....	....	5,830	5,948	29,942
1911	160,844	73.0	9,737	*Nil.*	....	....	3,402	3,457	48,552
1912	(*o*)50,684	23.0	2,766	*Nil.*	....	....	2,589	2,632	62,276
1913	63,620	29.0	4,365	0.18	0.16	22	1,282	1,303	25,954
1914	1,600,979	7.27	211,742	....	....	....	21	21	387
1915	3,146,135	14.27	786,766	....	....	8	237	241	4,706
1916	3,018,251	13.69	761,045	231	209	9,874	97	99	1,568

Year.	Cement.			Chemicals.					
				Salts of Potassium. (*f*)			Chloride of Lime.		
	Bbl. (*i*)	Metric Tons.	Value.	Lb.	Kg.	Value.	Lb.	Kg.	Value.
1907	20,697	3,754	$30,435	2,675,248	1,285,892	$75,470	*Nil.*	....	....
1908	9,552	1,734	11,455	1,046,689	570,445	34,505	121,511	55,116	$912
1909	4,198	762	6,312	2,332,386	1,058,251	66,352	13,964	6,334	292
1910	17,914	3,251	24,878	2,187,787	922,645	60,648	496	225	6
1911	8,529	1,547	14,095	2,731,792	1,239,133	67,297	17,804	8,076	241
1912	4,586(*p*)	791	8,419	4,932,143	2,237,814	103,425	400	181	8
1913	2,687(*p*)	460	4,075	8,660,837	3,929,599	162,467	13,260	6,016	333
1914	757(*p*)	130	1,038	8,760,640	3,974,882	204,423	15,990	7,255	291
1915	1,142(*p*)	197	2,209	3,005,825	1,363,433	279,660	120,126	54,489	2,496
1916	625(*p*)	108	814	825,461	374,427	107,578	*Nil.*	*Nil.*	*Nil.*

Year.	Chemicals. (*Continued.*)											
	Nitrate of Sodium.			Caustic Soda.			Soda Ash and Carbonate.			Sodium Salts, All Other.		
	Long Tons.	Metric Tons.	Value.	Lb.	Kg.	Value.	Lb.	Kg.	Value.	Lb.	Kg.	Value.
1907.	7,159	7,274	$370,048	(*l*)	.....	.....	3,100	1,406	$53	742,201	336,662	$16,099
1908.	9,955	10,113	514,799	(*l*)	.....	.....	4,645	2,104	77	834,207	378,726	18,255
1909.	8,233	8,365	377,571	(*l*)	.....	.....	(*l*)	.....	....	1,053,410	477,816	21,777
1910.	5,784	5,878	250,550	(*l*)	.....	.....	(*l*)	.....	....	333,427	151,282	11,767
1911.	6,787	6,896	269,274	(*l*)	.....	.....	(*l*)	.....	....	611,922	277,566	14,479
1912.	8,853	8,995	440,200	(*l*)	.....	.....	(*l*)	.....	....	431,407	195,685	9,416
1913.	5,560	5,653	295,111	(*l*)	.....	.....	(*l*)	.....	....	534,470	242,500	12,672
1914.	9,220	9,374	460,868	....	.....	.....	......	.....	....	....	....	13,654
1915.	22,743	23,109	1,123,761	....	.....	.....	......	.....	....	....	....	387,437
1916.	53,553	54,415	3,432,273	....	.....	.....	......	.....	....	....	....	251,351

Year.	Coal, Bituminous.			Copper.						Graphite.	
				Ore and Matte.			Pigs, Bars, Ingots, Old, and All Unmanufactured.				
	Long. Tons.	Metric Tons.	Value.	Long Tons.	Metric Tons.	Value.	Lb.	Metric Tons.	Value.	Long Tons.	Value.
1907....	1,947	1,978	$12,199	....	72	$29,791	995,555	451	$199,828	1	$41
1908....	4,759	4,832	16,313	2	....	....	718,541	326	93,148	....	......
1909....	3,128	3,178	8,532	434	2	50	1,058,528	480	135,952	16	976
1910....	3,734	3,894	13,761	*Nil.*	441	5,600	55,857	25	6,443	34	3,192
1911....	3,718	3,778	10,296	*Nil.*	....	....	200	0.1	52	*Nil.*	......
1912....	982	998	6,574	*Nil.*	....	....	1,020	0.5	132	*Nil.*	......
1913....	1,179	1,199	6,652	*Nil.*	....	....	557	0.3	135	1	44
1914....	21,390	21,747	118,241	*Nil.*	....	....	3,436	1.6	534	*Nil.*	......
1915....	1,343	1,365	8,966	*Nil.*	*Nil.*	*Nil.*	801,872	364	151,369	......	......
1916....	24,257	24,648	77,001	2,739	2,783	55,675	7,629	3.4	1,529	.....	......

Year.	Iron and Steel.											
	Pig Iron.			Scrap.			Bar Iron.			Rails.		
	Long Tons.	Metric Tons.	Value.	Long Tons.	Metric Tons.	Value.	Long Tons.	Metric Tons.	Value.	Long Tons.	Metric Tons.	Value.
1907.....	2,921	2,968	$86,420	157	160	$3,378	38	39	$3,959	*Nil.*	....	.....
1908.....	1,827	1,855	52,079	288	293	3,597	26	26	1,271	*Nil.*	....	.....
1909.....	720	732	25,936	....	....	......	20	20	1,500	*Nil.*	....	.....
1910.....	579	588	20,706	....	....	......	9	9	356	*Nil.*	....	.....
1911.....	1,837	1,866	73,987	100	102	1,373	12	12	635	*Nil.*	....	.....
1912.....	5,087	5,169	130.102	198	201	3,788	25	25	1,176	*Nil.*	....	.....
1913.....	765	778	29,257	70	71	771	68	69	6,099	49	50	$1,000
1914.....	218	222	14,105	186	189	2,136	13	13	1,007	*Nil.*	....	.....
1915.....	2,650	2,693	54,009	90	91	1,063	408	415	13,043	181	184	5,632
1916.....	961	976	63,555	244	248	4,667	24	24	2,137	19	19	503

Year.	Iron and Steel. (*Continued.*)									Lead and Mfrs.
	Steel, Ingots, Blooms, Etc.			Sheets and Plates.			Tin and Terne Plates, Taggers Tin.			
	Long Tons.	Metric Tons.	Value.	Long Tons.	Metric Tons.	Value.	Long Tons.	Metric Tons.	Value.	
1907...........	292	297	$25,974	14	14	$1,220	42.2	42.9	$1,813	$2,416,082
1908...........	33	34	9,822	66	69	3,441	4.7	4.7	351	3,101,953
1909...........	60	61	10,389	42	43	2,630	14	14	6,273	3,139,908
1910...........	121	123	24,867	96	98	6,122	....	....	....	2,511,850
1911...........	108	110	19,721	....	....	34,177	....	....	....	4,067,574
1912...........	470	478	57,743	58	59	6,786	175	178	15,886	2,704,062
1913...........	418	425	60,191	*Nil.*	....	....	1	1	250	2,107,796
1914...........	443	450	41,052	2	2	143	67	68	4,240	1,539,039
1915...........	153	155	27,262	88	89	6,112	139	141	9,018	1,082,948
1916...........	161	164	86,501	1	1	938	6	6	1,084	33,224

Year.	Salt.			Sulphur—Crude.			Tin in Blocks, Pig and Granulated.		
	Lb.	Metric Tons.	Value.	Long Tons.	Metric Tons.	Value.	Long Tons.	Metric Tons.	Value.
1906......	1,462,413	663	$1,129	403	409	$8,475	807	820	$650,411
1907......	1,166,049	529	1,686	301	306	5,759	562	571	492,415
1908......	2,525,945	1,146	9,352	380	386	8,500	244	248	156,761
1909......	1,617,705	734	1,700	16	16	284	441	448	294,649
1910......	2,124,983	964	2,173	5	5	145	620	630	467,526
1911......	449,025	204	646	*Nil.*	....	....	1,012	1,027	958,481
1912......	73,551	33	105	1,015	1,032	20,314	589	598	591,729
1913......	76,125,400	34,540	3,226	25	25	555	1,104	1,122	1,135,105
1914......	5,196,300	2,357	14,349	309	314	7,074	802	815	647,017
1915......	10,384.400	4,712	31,841	175	178	3,995	553	562	439,433
1916......	14,897,700	6,757	61,525	104	106	2,187	140	142	129,006

(*a*) From Summary of Commerce and Finance of the United States. (*c*) Total exports of coin and bullion: that is, includes both foreign and domestic. (*d*) Only approximately correct. The Bureau of Statistics reports only the value of silver ores exported, but a much larger amount of silver leaves the country in copper matte, which is classified as copper ore, and no record is kept of its silver contents. The gold in copper matte exported is not included in the exports of gold given in the above table. These figures include ore of both domestic and foreign origin. (*e*) Includes nickel oxide and nickel matte. (*f*) Includes chlorate, chloride, nitrate, and all other salts of potassium. (*g*) Includes gas oil and fuel oil, reported in barrels, but calculated to gallons, on a basis of 42 gallons to the barrel. (*i*) Barrel of 400 lb. (*m*) Does not include coal used for fuel on vessels for foreign trade. (*n*) Included in other manufactures. (*o*) Antimony contents of regulus, etc. (*p*) Barrel of 380 lb.

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